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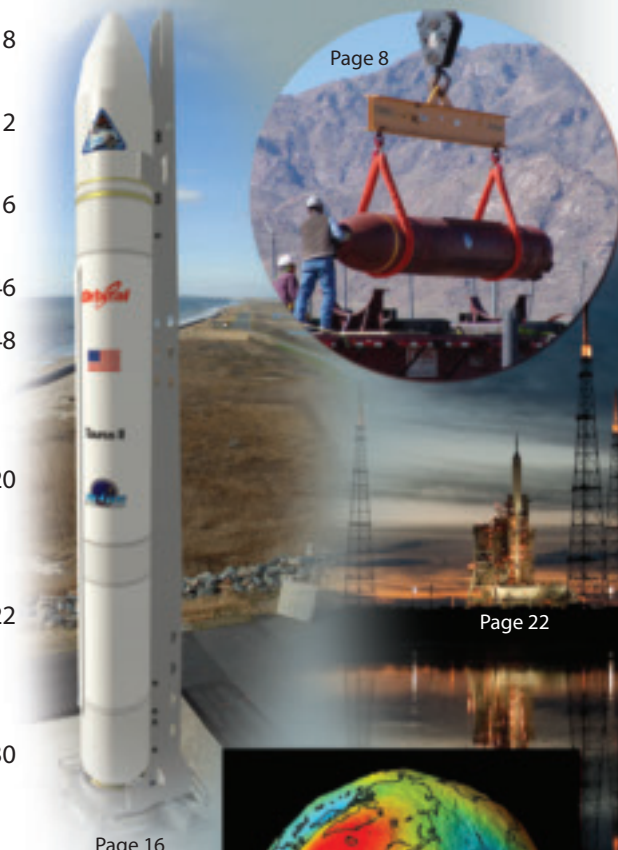

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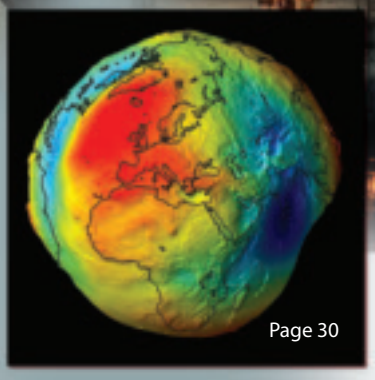

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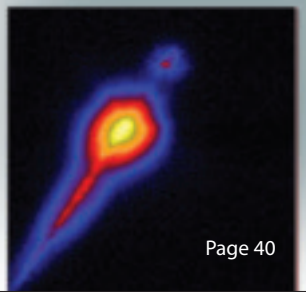

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This image of the Sun was taken taken immediately after the Atmospheric Imaging Assembly CCD camera on the Solar Dynamics Observatory cooled, on March 30, 2010. See the photo essay on page 20.

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Commentary

U.S. civil space policy: Clearing the fog

It is time to begin clearing the fog surrounding current U.S. civil space policy. Recent weeks have seen much airing of strong views both attacking and defending President Barack Obama's revised plans for human space exploration and related programs.

The foremost issue, in terms of U.S. international stature, is the half decade or more gap in U.S. capability for human transport to and from the space station. But retiring the shuttle after 30 years is certainly a valid step, both fiscally and in the interests of future crew safety. Shuttle technology is based on what we knew nearly a half-century ago: Imagine using 40- or 50-year-old information technology today! Constellation was also based on aged technology, though it is true that, as with the shuttle, much significant modern technology had been introduced. Besides, Constellation would also leave that gap.

Offering the private sector an opportunity to do what they've been clamoring for over at least the past two decades is also a step forward. If they succeed, it could help space transport emulate the highly successful satellite communications industry; if they fail, their contention will at least finally have been put to rest. The initial investment in commercial cargo transport to the ISS has already been committed, and will begin to show results, positive or negative, very soon. These contracts can then be used as indicators to assess the validity of Obama's planned $6-billion investment in commercial carriers. And the proven Delta IV and Atlas V are available, too.

Meanwhile the president is carefully hedging his bet. He plans to retain the Orion concept and the heavy-lift option characterized by Ares V. Together with the obvious need in any heavy-lift design for thrust augmentation by solid-propellant rockets, these actions could help ameliorate the economic impact of canceling Constellation, use some of the $9 billion already spent, and assuage the DOD's concern about loss of industry capability. A valid criticism is that this should start sooner—why wait until 2015?

Most important, the president's intent to invest in new technology initiatives could address the knottiest problem in human space exploration: reducing initial mass (and therefore cost) in LEO, with the corollary benefit of reducing transit times for astronauts' exposure to cosmic radiation. Two technologies that have been developed and could be demonstrated in less than a decade are upper stage nuclear thermal propulsion and orbital assembly. This aspect of the plan also addresses the issue of U.S. leadership in space. Other countries may get humans to the Moon sooner, but the best technology will win in the long term. The British Comet was the first commercial jet transport; the Boeing 707 came later. Which one dominated the skies?

Opponents point to a lack of specific goals and deadlines. But there *are* goals: extending the ISS to 2020 (and perhaps to 2028, as is now being studied); exploring near-Earth asteroids; building observatories at deep-space locations such as Lagrange libration point L2; returning to the Moon to set up observatories and search for water; and of course going to Mars. Perhaps the wisest element of the plan, however, is *not* setting specific deadlines or total costs of these missions. It is sheer fiscal irresponsibility to do so; we have no idea how much they will cost, nor how long they will take. But we do know that an annual NASA budget of about $19 billion is acceptable, and that would allow us to make substantial (and measurable) progress toward those goals, without emasculating any of NASA's other important functions.

As the fog clears, a new era of human space exploration will lie before us.

Jerry Grey
Editor-at-Large

"Smart" procurement falters in Europe

In March of this year EADS and its customers reached an agreement on funding for the Airbus A400M military transport. It entails a €2-billion increase on the original €19-billion contract for development and production of the aircraft, a further €1.5 billion of new funds for the project (in exchange for a share of future export sales), a waiver on current delay penalties and an accelerated rate of payment for aircraft between 2010 and 2014.


A-400M

Although this was an important breakthrough for both customers and manufacturer, the agreement has again highlighted the difficulties Europe has in procuring complex, multinational military equipment. In 2003 the unit cost of an A400M was around $80 million, and it was due to enter service in 2009; now, the unit cost is more likely to be between $120 million and $130 million, and the entry-into-service date is 2013.

Despite huge efforts to introduce "smart" procurement practices over the past 10 years, the trends are pointing to more cost overruns and further delays to future cooperative ventures.

Principles take shape

For the past 30 years Europe's industry and governments have been slowly moving toward a better understanding of how to procure complex military systems. The lessons of the Eurofighter Typhoon, the NH-90 helicopter and, most recently, the A400M programs have resulted in a clear set of basic principles that should underpin the acquisition of any complex, multinational military platform.

In essence, these principles are: Reduce the number of phases that require political authority; identify risk and risk reduction programs at an early stage (preferably the predefinition phase); and develop integrated teams of industry and customer/government qualified personnel, with real decision-making powers, to jointly manage key aspects of the program. If there are technical problems or delays as a result of budgetary issues—or a change in operational requirements—the expense for these should be allocated fairly between the government customer and industry.

"There is a tendency to have fewer phases (usually only three) in a program," according to a recent report, *Lessons Learned from European Defence Equipment Programs,* from the EU's Institute for Security Studies. "The first phase now consists of the predefinition phase, the second phase encompasses design/development—during which the technological risks are evaluated, and which currently lasts longer than in past programs. This third phase is the production phase. …In more complex programs sometimes there is a fourth phase between the definition and development phase, essentially the risk reduction phase (for simulations and pre-tests)."

Generally speaking, "smart procurement" means looking at the full life cycle of any new program at the very early stages, so system enhancements and upgrades can be planned and budgeted for many years in advance. It also means the roles of industry and government customers can be managed so technical and financial risks can be shared.

The U.K. strategy

The U.K. introduced its smart procurement initiative in 1988 and redefined it in 2001 as the "smart acquisition program." This became part of a broader new defense industrial strategy in 2005. The U.K. was the first European country to adopt smart procurement and "public/private finance initiative" acquisition policies, which have seen private contractors becoming responsible for military aircraft maintenance, pilot training, air traffic control and, most recently, the management of the RAF's air-to-air re-fueling operation.

A further defense industrial strategy will be launched in the next few years, as well as a new plan for acquisition reform, in which the Ministry of Defence (MOD) will establish procurement frameworks based on 10-year planning horizons.

Meanwhile, the MOD has streamlined its acquisition process for urgent operational requirements (UORs), approving over £3.6 billion of UORs for Iraq and Afghanistan since operations began, mostly related to protecting troops in the field. Recent UOR acquisitions have included General Atomics MQ-9 Reaper unmanned air systems—

with just 12 months between the original purchase request and the aircraft's use in operations by the RAF in Afghanistan—and airborne defensive aid suites.

Long-term difficulties

Although short-term acquisition processes have improved, many of the ministry's long-term strategic programs are late and over budget. The MOD ordered 21 Nimrod MR4 reconnaissance and surveillance aircraft for operation in 2003; this order has been cut to nine, with an operational date of 2012.

Pressure on defense budgets to reduce spending has also contributed to delays and cost overruns as equipment procurement is slowed down.

An independent audit into MOD acquisition processes commissioned by the U.K. government and released in October 2009 found that a consequence of using delays to manage the funding gap between available resources and acquisition commitments "has meant that programmes take significantly longer than originally estimated, because the Department cannot afford to build them at the originally planned rate…. Across a large range of programmes, this study found that the average programme overruns by 80% or around five years from the time specified at initial approval through to in service dates. The average increase in cost of these programmes is 40% or around £300 million. This study also estimates that the 'frictional costs' to the Department of this systematic delay are in the range £900 million-£2.2 billion per annum."

This is not good news for the next round of large equipment acquisition programs, such as the purchase of 140 Joint Strike Fighters and two aircraft carriers. According to a recent House of Commons defense select committee report, delaying the carrier program has generated £450 million in savings in the short term but added £674 million in the longer term (over 10 years) of the program.

French twist

In France, acquisition reform has taken a different turn. Responsibility for military purchases lies with the Direction Générale pour l'Armement (DGA), a state organization sitting between the armed forces and the Defense Ministry, staffed by highly qualified technical personnel with both industry and government experience, favoring fixed-price contracting but with flexible contractual renegotiating principles.

Eurofighter Typhoon

In France, as elsewhere, over 50% of all military equipment purchasing contracts are renegotiated at some stage. "In response, the French have introduced a 'responsibility principle' to fixed-price contracting, meaning that those who are actually responsible for failing to meet contractual obligations, whether government or industry, must generally pay the costs," according to a December 2009 U.S. Center for New American Security policy brief.

Although PFI (private finance initiative) government-industry contract deals are commonplace within the U.K., in France they are rare. One of the first was signed in 2007 between the Defense Ministry and the HeliDax company for the supply of up to 22,000 helicopter flight hours to the EA-ALAT (Ecole d'Application de l'Aviation Légère de l'Armée

NH-90

Events Calendar

JUNE 1-4
Fourth International Conference on Research in Air Transportation, Budapest, Hungary.
Contact: Andres Zellweger, dres.z@comcast.net

JUNE 7-9
Sixteenth AIAA/CEAS Aeroacoustics Conference, Stockholm, Sweden.
Contact: Hans Bodén, hansbod@kth.se

JUNE 8-10
Third International Symposium on Systems and Control in Aeronautics and Astronautics, Harbin, People's Republic of China.
Contact: Zhenshen Qu, ocicq@126.com

JUNE 14-18
ASME TurboExpo 2010, Glasgow, Scotland, U.K.
Contact: www.turboexpo.org

JUNE 28-JULY 1
Fortieth AIAA Fluid Dynamics Conference and Exhibit; 10th AIAA/ASME Joint Thermophysics and Heat Transfer Conference; 27th AIAA Aerodynamic Measurement Technology and Ground Testing Conference; 28th AIAA Applied Aerodynamics Conference; 41st AIAA Plasmadynamics and Lasers Conference; Fifth AIAA Flow Control Conference. Chicago, Ill.
Contact: 703/264-7500

JUNE 28-JULY 2
Eighth International LISA Symposium, Palo Alto, Calif.
Contact: Sasha Buchman, 650/725-4110

JUNE 30-JULY 3
ICNPAA 2010—Mathematical Problems in Engineering, Aerospace and Sciences, Sao Jose dos Campos, Brazil.
Contact: Prof. S. Sivasundaram, 386/761-9829, seenithi@aol.com

JULY 10-15
Twenty-seventh International Symposium on Rarefied Gas Dynamics, Pacific Grove, Calif.
Contact: Deborah Levin, 814/865-6435, dalevin@psu.edu

JULY 11-15
Fortieth International Conference on Environmental Systems, Barcelona, Spain.
Contact: 703/264-7500

JULY 18-25
Twenty-eighth Scientific Assembly of the Committee on Space Research, Bremen, Germany.
Contact: www.cospar2010.org

JULY 25-28
Forty-sixth AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Nashville, Tenn.
Contact: 703/264-7500

JULY 25-28
Eighth International Energy Conversion Engineering Conference and Exhibit, Nashville, Tenn.
Contact: 703/264-7500

de Terre), a helicopter training school in Dax, southern France.

Currently, according to the DGA, new military equipment procurement programs are running about two months behind schedule, with an increasing demand to meet new UOR purchases. Although a cause for concern, this suggests France is coping with complex military procurement issues somewhat more successfully than is the U.K.

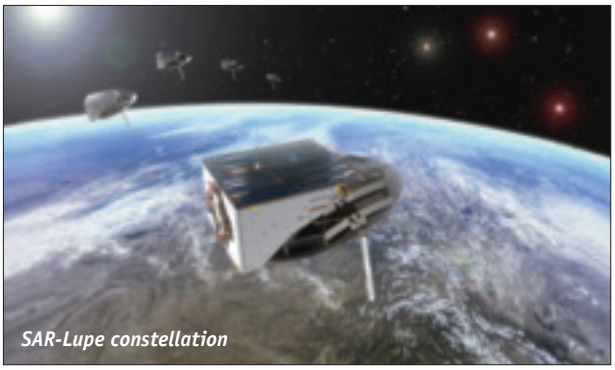
But a recent government audit of all military programs since 2005 costing more than €5 billion—including the Dassault Rafale, NH-90 helicopter, A400M airlifter and Eurocopter Tiger helicopter—has shown that 75% of these major projects are impacted by delays or cost overruns. Among the main reasons for these problems, according to the audit, have been underfunding of programs, underestimation of program costs, international cooperation terms that have driven up costs and the simultaneous launch of several large programs.

Pressures grow

With increasing pressure on the defense budget, it is likely that delays and overruns will escalate in the coming years, in France and elsewhere. The delays and cost overruns to the A400M program will not help the cause of those convinced that private contractors need to be given more responsibility for managing complex new defense equipment programs.

The U.K. and France are not the only major European countries to consider a fresh overhaul of defense equipment procedures. The new German defense minister, Karl-Theodor Freiherr zu Guttenberg, has promised to improve the future German acquisition policy. The A400M delays, coupled with the controversy of the EADS KC-X tanker bid and a naval fleet-support ship contract that is well over budget, have concentrated minds in the German defense ministry on how far smart procurement principles should be taken.

Ironically, it was the poor performance, in terms of delays and cost overruns, on the multinational Eurocopter Tiger and the NH-90 military transport helicopter that persuaded the German defense ministry that EADS would have to bear so much of the brunt of costs and



SAR-Lupe constellation

compensation if the aircraft were delayed or if it underperformed, a policy that seems to have backfired.

Like France, Germany has been fairly slow in adopting smart procurement principles, one of the first being the €320-million military SAR-Lupe satellite constellation, a global military surveillance system able to operate night and day, independent of weather conditions, delivering up-to-date, high-resolution images from virtually all regions of the world. Responsibility for managing the system was given to a consortium of companies led by OHB-System AG.

The first satellite was launched on a Russian Cosmos 3M launcher in December 2006, and all five satellites are now in place. Delivery of the overall system was officially accepted by the customer, the German Federal Office of Defense Technology and Procurement BWB, in September 2008, on time and within budget; OHB is under contract to operate the system for 10 years.

But Germany, like the rest of Europe, now faces some tough choices on major strategic programs such as the Franco-German-Spanish EADS Talerion ISTAR (intelligence, surveillance, target acquisition and reconnaissance) UAV, where a decision on the future of the program is due to be made this year.

✈✈✈

The current economic crisis should mean that governments will look increasingly for private industry partners to take more responsibility for managing and supporting complex new military systems. But there is little evidence that, beyond the U.K., this is happening. Rather, in these straitened times, politicians are coming under increasing pressure to support their domestic industries, delay expensive decisions on major programs for a few more years and concentrate on short-term troop protection acquisitions to support expeditionary operations.

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Disagreements and hard decisions

When President Barack Obama appeared at the Kennedy Space Center in Florida on April 15 to announce a shift in human spaceflight policy, he drew praise from several advocates of private-sector spacecraft development, including Apollo 11 astronaut Buzz Aldrin (see "Conversations," page 12). He also took lumps from critics who say the White House is grounding U.S. space efforts.

On the Hill, the USAF tanker issue remains unresolved, and "prompt global strike" is on the DOD's radar screens.

Defining the human space effort

The president is seeking to extend funding for the international space station until 2020 and wants NASA to pour $6 billion into developing commercial space taxi services to give astronauts access to the station in the postshuttle era.

Obama also wants to kill the Constellation program, including the Ares rockets NASA has been developing for six years at a cost of $9 billion. It does retain a scaled-down version of the program's Orion crew exploration vehicle, which would be launched, unmanned, to the station and be parked there as an emergency rescue vehicle but would not, as previously planned, take astronauts to the Moon and beyond. The president said it would still be possible for U.S. astronauts to reach Mars in the fourth decade of this century, but enunciated no specific plan for achieving this.

Sen. Kay Bailey Hutchison

Sen. Barbara Mikulski

Many in Washington believe that designing, developing and flying spacecraft is a strength of the government agency that has done the job for the past half-century and that the private sector—even with federal funding—is not yet ready to take over the building of the only U.S. spacecraft that will carry crews. Others feel, despite White House assurances, that shifting to private-sector spacecraft will cost jobs during a time of economic challenge. One Washington observer says the administration's policy "is not yet a done deal," because it faces robust opposition on Capitol Hill.

Moreover, astronaut Neil Armstrong, the first person to walk on the Moon, joined two other Apollo veterans in expressing "substantial reservations" about the administration's plan. If the policy is implemented, Armstrong, Jim Lovell and Gene Cernan wrote, "It appears we will have wasted our current $10+ billion investment in Constellation" and that "the United States is far too likely to be on a long downward slide to mediocrity." Public utterances by the almost reclusive Armstrong—in this case, differing with his crewmate Aldrin—are very rare and are taken seriously in the nation's capital.

Following the president's statement and the astronauts' letter, NASA administrator Charles Bolden went to Capitol Hill on April 22 to defend the policy change. Sen. Richard Shelby (R-Ala.) charged that Bolden is an "impediment to moving forward" who lacks credibility among lawmakers. Shelby also accused the administrator of ceding human space exploration to the Russians, the Chinese and the Indians.

Similarly critical if more soft-spoken, Sen. Kay Bailey Hutchison (R-Texas) told Bolden that NASA is "relying too heavily on commercial entrepreneurs who [won't] be ready to send astronauts into space anytime soon." Sen. Barbara Mikulski (D-Md.) was easier on Bolden but questioned the new policy, asking, "How could a commercial vehicle be able to meet a three-year timeframe" for launching astronauts. Apparently not yet decided, Mikulski said she will formulate her position on the administration's budget request for NASA "only after more hearings and further research."

Tanker déjà vu (again)

The Air Force's decade-long effort to acquire a new air-refueling tanker took a new turn April 21 when EADS announced that it will enter the $35-billion KC-X competition. Previously partnered with Northrop Grumman, which decided in March not to participate, EADS will challenge Boeing for an opportunity to build 179 aircraft to begin replacing 50-year-old KC-135 Stratotankers.

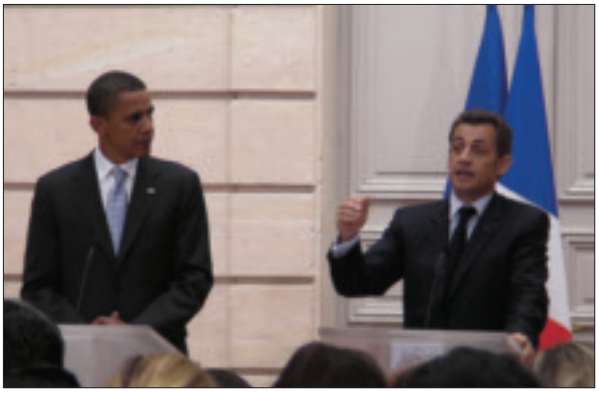
Air Force officers say privately that either of the aircraft likely to be submitted as a KC-X entry would serve their needs. Boeing is expected to press ahead with a version of its 767-200, which is smaller and has less fuel and cargo capacity but is likely to have lower maintenance and operations costs. EADS will propose a version of the Airbus A330-300, which it now calls the KC-45, that is more robust and can offload more fuel, but may be larger than

what the Air Force needs. (For a brief period, KC-45 was the official military designation for the next-generation tanker but it is now an industry term.)

Boeing has the advantage of already operating a production line in Everett, Washington, and an outfitting facility in Wichita, Kansas, but has not yet put a prototype of its proposed tanker into the air or tested its proposed advanced air-refueling boom. EADS plans to build an assembly line in Mobile but is still a long way from dipping its first spade into the Alabama earth. EADS has a "production representative" version of its KC-45 and of its advanced refueling boom in the flight test stage. Each company claims that its aircraft can be ready on Air Force ramps sooner than the other.

As the tanker competition ramps up once again, the KC-135 soldiers on.

The KC-X competition evokes powerful feelings at the highest levels in the nation's capital and overseas. French President Nicolas Sarkozy said on March 30 that he trusts Obama's promise that the tanker competition will be "free and fair." Many in Washington heard Sarkozy's words as a plea, if not a demand, rather than an assurance of a high comfort level. Standing beside the French president at a low-key press conference, Obama repeated that the KC-X would be a fair competition. He also told reporters that he has no intention of usurping Defense Secretary Robert Gates' control over the competition.



President Obama and French President Nicolas Sarkozy held a joint press conference on March 30.

This was the latest of several statements by key figures stressing that the KC-X competition will be as fair as humans can make it. In fact, that emphasis on fairness means that Gates is recused from the selection process, which will be conducted by acquisitions professionals, to avoid the appearance of unfair command influence.

Pentagon officials extended a deadline for KC-X bids from May 10 to June 9, a move that benefits EADS. Boeing says it was ready to offer its tanker on the earlier date.

This project, more than any other aircraft program—even the behind-schedule, over-budget F-35 Joint Strike Fighter—evokes strong feelings in Congress as well. Sen. Patty Murray (D-Wash.) issued a statement criticizing the inclusion of EADS, pointing to a recent World Trade Organization finding that Airbus's parent company received illegal subsidies from involved European governments.

Sen. Shelby, on the other hand, said the EADS tanker would create more jobs and give the Air Force a better plane. Split on which plane and which planemaker to support, Capitol Hill lawmakers are likely to object to any decision ultimately reached by the KC-X acquisitions team.

Prompt global strike

The Obama administration has asked Congress for $250 million in FY11 to continue exploring a new weapon that uses an ICBM to boost an unmanned spaceplane into the upper atmosphere. Once called "precision global strike" and now renamed "prompt global strike" to emphasize its potential for rapid response capability, PGS would enable the U.S. to transport a conventional warhead to a high-value target in as little as an hour. Partly in support of PGS, on April 22 the Air Force launched an Atlas V rocket from Cape Canaveral carrying X-37B orbital test vehicle 1, a 29-ft,

Sen. Patty Murray

On April 22 the Air Force launched an Atlas V rocket carrying this X-37B orbital test vehicle.

11,000-lb unmanned space shuttle that can remain in orbit for months and land via remote control.

The Air Force "doesn't know when it's coming back," Gary Payton, deputy undersecretary for USAF space programs, told reporters. Without confirming a link between PGS and the X-37B mission, Payton said of the latter, "I don't know how this could be called weaponization of space. It's just an updated version of the space shuttle-type of activities in space." Others say an LGM-30G Minuteman III ICBM body will eventually replace the Atlas V and be melded with an upgraded X-37B to become an operational PGS system. Funding for a more conventional next-generation bomber is being postponed while the Air Force proceeds with PGS work.

Because PGS is suborbital, it will not violate international agreements or long-standing tradition against putting warheads into orbit. Still, previous administrations led by both parties have resisted using ballistic-missile-style rocket boosters to launch conventional weapons because of the hairtrigger alert status of U.S. and Russian ICBM forces. Almost unnoticed by the public, Washington and Moscow continue to maintain hundreds of ICBMs in "launch on warning" mode, meaning that one superpower would unleash its missiles if it believed it was about to be attacked by the other.

At a high-level meeting in 2006, Russia's then-President Vladimir Putin told President George W. Bush that he opposed a PGS-type weapon because Russia would not know if a newly launched missile carried a conventional or a nuclear warhead. Acknowledging that the idea "really hadn't gone anywhere in the Bush administration," Defense Secretary Robert Gates, who also held the top Pentagon post under Bush, told ABC's "This Week" that the Obama team has "embraced" a conventional weapon that uses a rocket booster.

The appeal of PGS was spelled out by David E. Sanger and Thom Shanker in an April 23 *New York Times* article. The new weapon, they wrote, "is designed to carry out tasks like picking off Osama bin Laden in a cave, if the right cave can be found; taking out a North Korean missile while it is being rolled to the launch pad; or destroying an Iranian nuclear site"—all without the U.S. being forced to resort to nuclear weapons.

The U.S. will soon have a slower response version of the same capability using the B-2 Spirit stealth bomber and the Air Force's massive ordnance penetrator (MOP), a 30,000-lb bunker-busting bomb scheduled to join the B-2's arsenal after a flight program is concluded later this year. Development of the MOP is widely understood to be a direct response to Iran's nuclear development program, which includes extensive underground construction.

The flight program for the massive ordnance penetrator should be concluded later this year.

All 20 operational B-2s belong to the 509th Bomb Wing at Whiteman AFB, Mo. Brig. Gen. Robert Wheeler, 509th commander, told Angus Batey of the *London Daily Mail*: "The MOP can hold any target at risk. It's a psychological deterrence weapon as well as a capability. There's no leadership that can hide from that particular weapon."

A source told *Aerospace America* that the Pentagon wants to be able to act quickly on short-notice intelligence and to attack a high-value target "within minutes rather than over a period of hours." The advantage of a Minuteman/X-37B PGS weapon over the B-2/MOPS combination lies only in the timing: Launched from Whiteman, a B-2 would take 10 hr to reach a target along the Afghanistan-Pakistan border; a missile-boosted spaceplane might reach the target in an hour.

While the April 22 X-37B launch—about which, apart from Payton's comments, nothing has been said publicly—is part of the PGS effort, other pieces of the program are in the DOD's "black" budget and apparently include vehicles that have not been revealed in public. A senior source told this column that a part of the program is located at the Air Force's Groom Lake, Nev., facility.

The issue that must be resolved in Washington: Given the very high (but as yet unknowable) cost of a PGS system, does the nation really want to give up a next-generation bomber for it? A skeptic pointed out that bin Laden is probably living in a house, not a cave, and that the U.S. would have blown down the roof long ago using existing technology if leaders possessed accurate intelligence on the al-Qaeda figure's whereabouts.

The nation's leaders must also determine whether the U.S. can field a PGS capability without violating at least the spirit and possibly the letter of existing arms treaties, including a pact signed by Obama and Russian President Dmitri A. Medvedev in Prague on April 8.

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Buzz Aldrin

The whole world saw you walking up the stairs to Air Force One last April arm in arm with President Obama. You were headed to the space conference in Florida. What were you talking about?

He thanked me for my help in supporting his space plan.

That's it?

He's a very smart guy.

Much of the program you've advocated for years is included in the new plan. Do you feel vindicated?

No, because there is a lot of work to be done. We didn't get everything we sought.

What, for example?

There is still a need to develop a runway lander type vehicle for the space taxi, not a space capsule. And I urged the shuttle be extended so as to speed the development of a shuttle-derived heavy-lift vehicle. That doesn't seem to be likely now.

So you have no use for capsules?

No, I didn't say that. Making the space taxi that flies to and from the international space station a capsule is a pretty dumb idea. But a space capsule would work in a deep space mission.

"Making the space taxi that flies to and from the international space station a capsule is a pretty dumb idea."

What difference does it make?

A space taxi, by definition, should be able to return crew and ISS experiments to a runway to speed their processing and to carry the larger payloads that a lifting body runway lander can deliver. A space capsule shape strongly limits the down mass and increases the *g* forces sustained during reentry. I have flown reentry profiles aboard capsules, and I can tell you that delicate samples coming home from the ISS would sustain a more benign environment aboard a glider.

Now, for deep space missions, a capsule would be preferred for its ability to aerocapture and to otherwise sustain reentry speeds coming back from a deep space or planetary entry. There, wings and a lifting shape become problems for the heat shield and the higher heating loads and *g* forces. So I think an Orion-like vehicle would be preferred for use with a deep space vehicle, and a lifting body preferred for returning taxi missions from ISS. Each has a place.

For years, policymakers have ignored many of your ideas. Now they're being codified into policy. Why now? What has changed?

Things are really bad, and that's when change becomes possible. Government bureaucracies aren't known for their ability to make substantial changes; they're not very agile. NASA faces difficult times in transitioning from the shuttle era to an agency more focused on research and deep space manned flight.

This opens up the possibility of hearing new approaches. Under Constellation, the program of record was falling so far behind schedule that there was no funding to build the Ares V or the Altair lander. It needed all of the funding just for "Apollo on steroids." That's because under [former NASA Administrator] Mike Griffin the focus became returning to the Moon, rerunning the Moon race we won 40 years ago.

I have had a unified strategic vision for space that is appropriate for the 21st-century world we face. The Cold War is over. Today, to demonstrate global space leadership requires that you collaborate and build coalitions with other nations, not see them as competitors. But Charlie Bolden has a tough job ahead of him as he wrestles his agency into a new focus. The forces that support the status quo are very entrenched.

So you'd abandon the Moon entirely?

No, I believe we should go back to the Moon, only this time as part of an international partnership that establishes a lunar development authority. We are a great power and have the experience to help the other nations that want to develop the Moon. Same for the station. Our role today is to express our leadership by facilitating the space programs of our partners.

"Things are really bad, and that's when change becomes possible."

China, India, South Korea, Brazil all are seeking to develop advanced space programs, some of which include manned space programs. We can help make that a reality. And when we do, our stature increases, which strengthens our strategic interests.

Why the focus on Mars for all these years?

Our survival requires us to become a true multiplanet species. We need to identify places we can go in the solar system that could be candidates for habitation and colonization. Mars offers us tremendous scientific benefits, in understanding global climate change, possible life—and even, during the period when it was wet, advanced life. It is the best candidate we know of to support a human colony. So that's why Mars should be our focus, not the Moon.

What's the relationship between Mars and heavy lift?

A heavy-lift system is a better way to launch an interplanetary deep space vehicle into low Earth orbit than two vehicles. Using today's EELVs would require half a dozen launches of small

packages; that would not be desirable. To go anywhere beyond Earth orbit requires greater lift than we have today.

So you endorse the president's proposal to speed up a heavy-lift vehicle?

It won't take us five years to design.

How long would it take?

If we used the existing space shuttle infrastructure we could start now. That's why shuttle extension was so critical. But that doesn't seem to be in the planning, so we may have to change course and try a "clean sheet" approach.

You no longer favor a shuttle-derived heavy-lift design?

That's my preferred approach, but without shuttle extension you lose the workforce and the shuttle systems. So an entirely new approach may be needed.

And you didn't support the Ares I and Ares V vehicles?

The Ares I used five-segment motors that were unproven and underpowered for the weight of the Orion. And Ares V was too big. So it was clear to me that we needed a different approach to heavy lift.

How can NASA develop a deep space vehicle under their budget pressure?

If we utilize the spare parts left over from the ISS construction, or inflatable technology, we can get at least to the prototype stage fairly quickly without a huge expenditure of funds. There is always the tendency to go for the most expensive approach, the Cadillac, when something cheaper is available. The idea is to get us out into deep space as soon as we can start.

What is the most difficult thing about a manned Mars mission?

We don't have the technology to sustain a Mars crew for the long trip required by chemical rocket propulsion systems. That's why we need to develop capabilities like the VASIMR plasma rocket and other designs, to shrink the transit times to Mars or asteroid rendezvous. We also need more research in radiation shielding. And a heavy-lift booster and possible advanced upper stages. We should be working on these areas now, and I think the new R&D budget supports this. In-space refueling of upper stages is a technology we should develop.

Recently the LCROSS [Lunar Crater Observation and Sensing Satellite] mission detected substantial amounts of water on the Moon. Would you take advantage of this in your Mars scenario?

Robots can mine the water on the Moon, and we could teleoperate those robots from a deep space vehicle on a lunar flyby test flight—or by students back here on Earth. You don't need a

Buzz Aldrin was educated at the U.S.Military Academy at West Point, graduating third in his class with a B.S. in mechanical engineering. He then joined the Air Force, where he flew F-86 Sabre Jets in 66 combat missions in Korea, shot down two MiG-15s and was decorated with the Distinguished Flying Cross. After a tour of duty in Germany flying F-100s, he earned his doctorate of science in astronautics at MIT and wrote his thesis on manned orbital rendezvous.

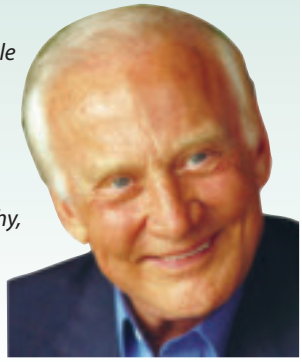
Selected by NASA in 1963 into the third group of astronauts, Aldrin was the first with a doctorate and became known as "Dr. Rendezvous." The docking and rendezvous techniques he devised for spacecraft in Earth and lunar orbits became critical to the success of the Gemini and Apollo programs and are still used. He also pioneered underwater training techniques, as a substitute for 0-g flights, to simulate spacewalking.

In November 1966 during the Gemini 12 mission, he performed the world's first successful spacewalk, overcoming prior difficulties experienced by Americans and Russians during extravehicular activity and setting a new EVA record of 5 hr 30 min.

On July 16, 1969, Aldrin, Neil Armstrong and Michael Collins were launched aboard the Apollo 11 mission. On July 20 Aldrin and Armstrong landed their lunar module, Eagle, on the Moon's surface, spending 21 hr on the Sea of Tranquility. Apollo 11 returned 46 lb of Moon rocks, the first lunar samples to be returned by an Apollo crew.

Upon returning from the Moon, Aldrin was decorated with the Presidential Medal of Freedom, the highest U.S. peacetime award. A 45-day international goodwill tour by Aldrin and the crew followed, with 23 other countries bestowing numerous distinguished awards and medals. Asteroid 6470 Aldrin is named for him, as is the Aldrin Crater on the Moon.

Since retiring from NASA and the Air Force, Aldrin has devised a master plan for missions to Mars known as the Aldrin Mars Cycler—a spacecraft system with perpetual cycling orbits between Earth and Mars. He has received three U.S. patents for his schematics of a modular space station, Starbooster reusable rockets and multicrew modules for spaceflight. Aldrin founded Starcraft Boosters, a rocket design company, and the ShareSpace Foundation, a nonprofit devoted to advancing space education, exploration and affordable spaceflight experiences.



Aldrin published an autobiography, Magnificent Desolation, *in 2009.*

Moon base to do that. And when we do return to the Moon, the lunar development corporation will set out extraction plans and those nations that wish to will participate.

"There is always the tendency to go for the most expensive approach, the Cadillac, when something cheaper is available."

If you compare your Apollo 11 flight to an asteroid rendezvous mission today, which would you say is the more difficult to accomplish?

The asteroid mission will be very challenging, but it's a good precursor to missions to Phobos and Mars settlement.

Why Phobos? Why not just go straight on to a Mars landing?

Because the gravity on Phobos is substantially less than Mars, meaning that missions to Phobos can build a sustainable base, and building our first settlement off-world would be less complicated on Phobos.

Why is an asteroid mission a good precursor to a Mars mission?

It tests many of the same technologies, plus planetary defense. Unless we want to go the way of the dinosaurs, we need to understand these NEOs [near-Earth objects] and develop ways to deflect any that may threaten the Earth in the future. Under the Constellation program there just wasn't any funding available for any of this.

What are the technologies needed for the asteroid mission?

First is a heavy-lift launch system, preferably with an upper stage that can be refueled. You'd launch the stage, and after it performs its [injection] mission it remains in space, available for the next payload. The HLV [heavy-lift vehicle] would use the new hydrocarbon booster engines called for in the FY11 budget, new stronger but lightweight stage structures and bulkheads, a new launch facility in Florida that incorporates shuttle experience along with the experiences of other launch systems. Perhaps horizontal vehicle processing. The trajectory for the asteroid intercept would be highly optimized for minimal transit times.

Then the design of the spacecraft. The habitat would have to be sized to accommodate both the crew and optical instruments and telescopes, the ability to catalog data from observations. Some means to possibly either land on an asteroid or extract a sample and bring it back into the ship. A capsule like Orion docked to one end that can become a lifeboat in an emergency, but also perform an aerocapture maneuver at the end of the flight. The capsule could dock with a runway lander lifting body for the return trip back to Earth, or land itself.

Above all, the technology to allow the crew to survive the high-radiation environment. New in-space propulsion systems to maneuver around the asteroid once the capsule/habitat is in orbit, and the propulsion to break out of orbit to the return trajectory.

None of these capabilities exists today. Ideally, I would like to see that HLV be fully reusable at some point, which would require flyback boosters.

Why not just build new Saturn Vs?

The technology is dated, as are the engines, structures and guidance. Plus the tooling and construction facilities are gone. The best approach is either an interim step, which would be an all-cargo shuttle-derived solution using the shuttle facilties, workforce, engines, tank and boosters, followed by the new design. You may have to get there in incremental steps. But an advanced reusable vehicle should be our technological objective.

There has been concern over the shift in space taxi services from Orion CEV/Ares I to commercial entrepreneurs. You've supported this change. Why?

Private contractors are well within the capability to carry both crews and cargoes to the station. NASA can oversee that while shifting to a focus on exploration missions. Routine space transportation can be performed by commercial industry. Gives us more options and a greater number of systems that can be developed.

Isn't there a risk in trusting the lives of astronauts to unproven vehicles?

They won't be unproven by the time astronauts fly on them. They will have to follow man-rating requirements and submit to NASA regulation.

Your former colleagues, like Neil Armstrong, Jim Lovell and Gene Cernan, don't agree—they call this shift the end of American human spaceflight.

A commercial industry that will have multiple crew vehicles flying in space, NASA developing Orion for deep space missions, a manned, heavy-lift launch vehicle, a budget that increases $6 billion over five years—how is that the end of human spaceflight?

You call your ideas a unified vision. How is it unified?

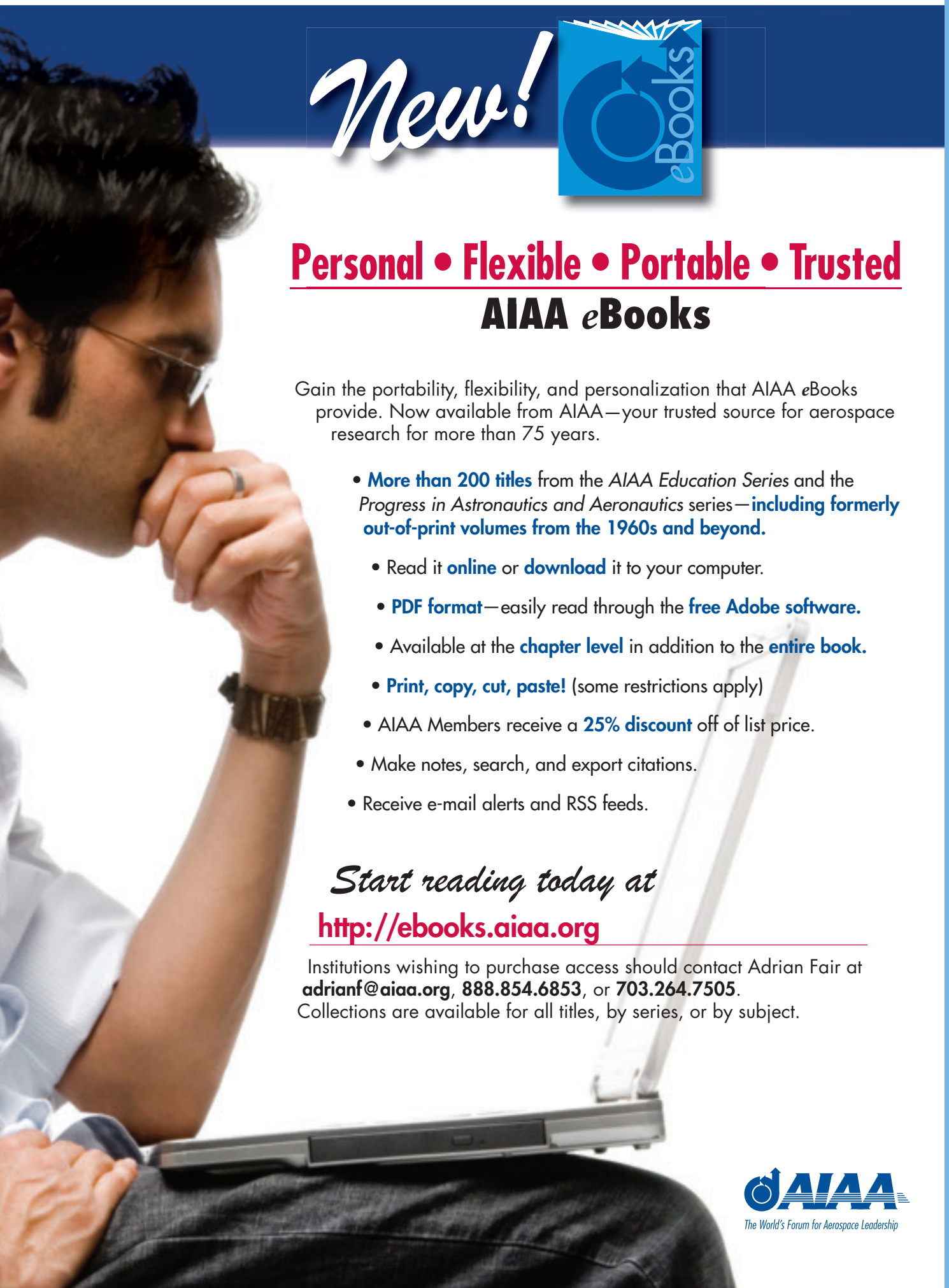
It combines exploration, commercial development, science and security. Furthermore, all of the elements support each other—shuttle extension to speed the development of heavy lift, runway landers for ISS taxi services, a capsule and habitat for deep space missions, partnering with other nations to advance use of the ISS and the lunar surface, missions to Phobos that establish the technology for colonization of Mars. It's a strategic approach.

Okay, I have to ask about [your TV appearance on]* Dancing with the Stars. *Why did you do that?

To call attention to the successes of the Apollo program and get people to think about the future, support our military personnel, those who also supported our space program, and old geezers like me.

So you admit to being an old geezer?

I wanted to show people of my age that you can go out and get up and *try* to do new things. Be active. I'm 80 years old, so if I can do it so can you.



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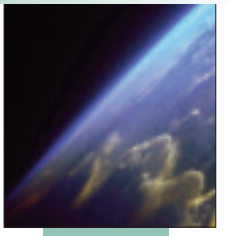


U.S. space launch: Growth and stagnation

SPEAKING AT THE SPACE FOUNDATION'S 26th National Space Symposium this April, Gwynne Shotwell, the president of Space Exploration Technologies, or SpaceX, noted the importance of growing the space launch services market. Shotwell was part of a panel discussing the "changing paradigm" of how the Pentagon and NASA fulfill their requirements for products such as satellite imagery and human/cargo spaceflight services. The topic was prompted by the termination of NASA's Constellation program in February and the realization that the U.S. will soon be without a national human spaceflight capability.

Once the space shuttle fleet is retired later this year or early next, the U.S. government will no longer be in the business of owning and operating its own piloted space launch vehicle. NASA is preparing to embark on a new operating plan that will require it to depend initially on the Russians and their Soyuz rockets and Soyuz/Progress capsules, then eventually on U.S. companies like SpaceX and Orbital Sciences, firms that offer leased capacity on their own commercially marketed space vehicles.

Shotwell's comment about the need to grow the market in which her company competes was said in a matter-of-fact way and was so generic and obvious that it failed to elicit a follow-up question from the moderator or to stimulate an exchange with any of the other panelists. This was unfortunate, because it missed an opportunity to address a key question for both NASA and the U.S. launch services industry as the paradigm shift in U.S. human spaceflight emerges: How do you keep the industry from growing overly dependent on NASA, becoming discouraged from competing for other business and thus having its spirit of innovation damaged?

As the paradigm shifts, it would be shortsighted for the U.S. launch services industry to emphasize growth in its volume of business without giving equal or more attention to diversifying its customer base. While it makes sense for NASA, for example, to serve as a guaranteed anchor client that will help SpaceX and Orbital Sciences lower their financial risk as they develop the Falcon 9/Dragon and Taurus II/Cygnus launch systems, this should be viewed as only an initial incentive for these and other companies to enter and help expand the market for commercial human/cargo spaceflight services.

Teal Group thinks it would be a huge mistake for companies like SpaceX and

In the early going, the U.S. will rely on Soyuz and Progress capsules (below, docked at the ISS) and Soyuz rockets (left) for access to the space station.

The Taurus II is Orbital's proposed vehicle for delivering cargo to the station.

Orbital's Pegasus rocket pioneered the use of air-launched expendable launch vehicles.

Orbital to view NASA as "the market," rather than as one of many potential customers within many different markets—most of which have yet to be invented. It would be a mistake because it could transform these companies from hungry, innovative enterprises into conservative and sluggish corporations that prefer maintaining a status quo to taking risks with new technologies and market applications.

The whole point of the Obama administration's push for a paradigm shift in the way the U.S. does human spaceflight is to energize an industry that has for too long been dominated by and dependent on the U.S. government. Although the decision to end Constellation and embark on a new vision for spaceflight was based largely on the fact that NASA cannot afford to develop and operate its own human-rated launch vehicle, the reality is that the policy change presents a historic opportunity for private industry to lead.

But leading, by its very nature, implies being creative, taking chances and exhibiting a willingness to be a pioneer. Both SpaceX and Orbital Sciences have displayed these qualities in the past and appear to be continuing the tradition with the Falcon 9/Dragon and Taurus II/Cygnus systems.

Risks pay off for Orbital

Orbital pioneered the use of air-launched expendable launch vehicles when it introduced its winged Pegasus booster in 1990. It was among the leaders in development and operation of LEO mobile communications satellites with the deployment of its first-generation Orbcomm constellation in 1998-1999.

During the second half of the 1990s, the company also went against the prevailing trend toward heavier geostationary commercial communications satellites, opting instead to build and market small to medium-sized versions. The bet paid off on March 22, 1999, when the Broadcasting Satellite System of Japan awarded a contract to Orbital for the BSAT-2A and -2B direct TV broadcast satellites. Each satellite has a mass of 1,317 kg and is much smaller than traditional geostationary commercial communications satellites. That contract was followed up quickly by additional awards for small geostationary satellites from that company and PanAmSat.

In short, Orbital has developed technologies and either met market demands that had previously gone unfulfilled, or outright stimulated the creation of a new market.

Fast rise for SpaceX

SpaceX has not been in existence nearly as long as Orbital; it was founded only in 2002. This makes its current leadership position in the evolving transition away from government-dominated human spaceflight all the more impressive. The

The second Falcon 1 launch delivered the 180-kg RazakSAT in July 2009.

SpaceX is developing the Falcon 9 for delivery to the ISS.

company has accomplished probably more than any other commercial launch venture in such a short period of time, and it has done so primarily as a result of dogged determination.

Although SpaceX had the advantage of being almost entirely financed by its founder, Elon Musk, through 2006, it has had to overcome three consecutive failures of its Falcon 1 rocket during 2006-2008. For an established launch firm with a proven record in the industry, three straight unsuccessful missions would likely have spelled the end of a program, as occurred with Boeing's Delta III in 1998-2000. One could reasonably have expected the same fate for the Falcon 1. Instead, with an undaunted entrepreneurial spirit, SpaceX pressed ahead.

On September 28, 2008, barely two months after its third failure, SpaceX achieved its first successful Falcon 1 launch from Omelek Island within Kwajalein Atoll in the Marshall Islands, deploying a 165-kg dummy payload it dubbed Ratsat to LEO. The second Falcon 1 was successfully launched on July 14, 2009. That mission, also launched from Omelek, delivered the 180-kg RazakSAT Earth imaging satellite to LEO for ATSB (Astronautic Technology Sdn Bhd) of Malaysia.

Despite its early series of failed missions, SpaceX managed not only to stay alive but to build a sizable launch manifest by convincing people of its technical viability. The company continued to win launch contracts from a diverse customer base that includes DOD, NASA, U.S. companies such as Bigelow Aerospace and Space Systems/Loral, as well as foreign governments and companies such as the Argentine space agency CONAE, EADS-Astrium of Europe, MDA of Can-ada and Spacecom of Israel.

Avoiding complacency

Given the histories of both companies, the last thing you would assume is that they would become complacent with the good fortune of having been selected by NASA to develop space vehicles that the agency may then lease over a period of at least six to eight years to haul cargo and astronauts to and from the ISS. But the Commercial Cargo Resupply Services contracts announced by NASA on December 23, 2008, are worth $1.9 billion to Orbital and $1.6 billion to SpaceX, and potentially much more if you add crew transport and more resupply missions.

All this is based on the U.S. operating the ISS until 2016. However, there is already strong support within the administration and Congress to extend the station's operational lifetime through 2020, so the real NASA business prospects for the two companies could become much more significant.

So the question is, will such a lucrative captive government market kill the pioneering and aggressive corporate cultures of these two companies and gradually make them less commercially competitive?

A cautionary tale

The scenario is not without precedent within the U.S. launch services industry. All you have to do is look at what the Air Force's Evolved Expendable Launch Vehicle program has done to Boeing and Lockheed Martin. Conceived in the mid-1990s, EELV was meant to provide the DOD with assured and affordable access to space by developing two new launch vehicle families based on modern and standardized stages, solid-rocket engines and payload fairings rather than the eclectic mix of previous-generation Atlas, Delta and Titan rockets.

Because of standardized parts, the new Boeing Delta IV and Lockheed Martin Atlas V families that emerged from the EELV program were envisioned to be easier and cheaper to maintain. The vehicles were also designed to have fewer parts, consequently minimizing the amount of hardware that could malfunction and improving reliability.

Best of all, the new rockets were going to reduce launch costs sizably for the Defense Dept., particularly the heavier models that were expected to cost less than half the price of the Titan IVs. At the time, the per-mission cost of a Titan IV was estimated at $350 million

The optimistic price estimates for the two rockets were based partly on lower operating costs for the vehicles, but mainly on the assumption that Boeing and Lockheed Martin would compete for DOD payload batch launch contracts and, separately, that the companies' improved commercial business with their new vehicles would surely help offset costs to the government.

DOD would have two launch vehicle families from which to choose, thus ensuring regular ac-

The guaranteed market for the Atlas V (left) and Delta IV allowed the rockets' developers to become complacent.

EELVs were expected to cost less than half the price of the Titan IVs, at the time estimated at $350 million.

cess to space. It would have cheaper launch costs, thus allowing more flexibility in the number of satellites it could afford to launch. It was a good deal for the government.

For Boeing and Lockheed Martin, EELV also represented a good deal. Each company received $500 million from DOD to develop their vehicles and a long-term, exclusive launch market, worth billions of dollars, that was reserved only for them. All Boeing and Lockheed Martin had to worry about was competing against each other, and even then it was recognized that each would inevitably receive a certain minimal level of DOD business in order to keep its launch vehicle program active.

Unfortunately, however, the EELV story does not have a completely happy ending. DOD does have assured access to space because it does indeed have two modern launch vehicle families. However, the fundamental premise behind EELV, that having two competing programs would drive down launch costs for the U.S. government, was undone when the two companies opted to reduce their risks by joining together to form United Launch Alliance in December 2006.

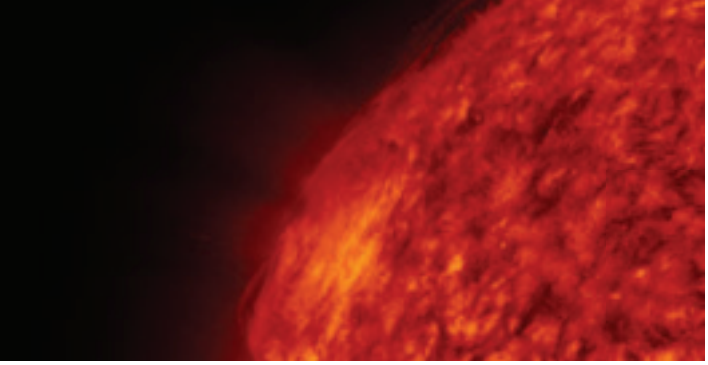
The joint venture guaranteed that neither Boeing nor Lockheed Martin would win big or lose big under EELV. In essence, the EELV business was so lucrative that it made the companies want to hedge their bets by coming together. It was a conservative move that made sense for two very established companies that preferred to play it safe. It was a bad move, though, from the standpoint of the U.S. taxpayer. DOD is not getting anywhere close to the launch prices it had hoped to get.

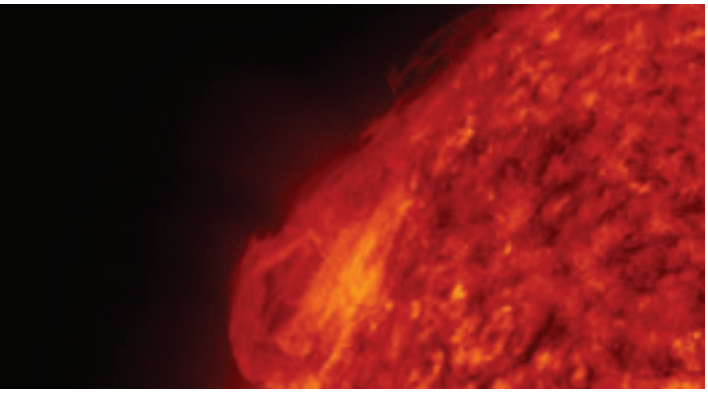
Perhaps a bigger factor in keeping Delta IV and Atlas V prices higher than expected is that both programs have become nonfactors in the commercial launch services market. It is as if whatever desire Boeing and Lockheed Martin may once have had to compete commercially against the likes of Europe's Ariane 5 and Russia's Proton had been undermined by EELV. After all, why bother to spend resources marketing your vehicle and bidding on launch contracts that you are not certain to win when you have a market that is both adequate and a sure thing?

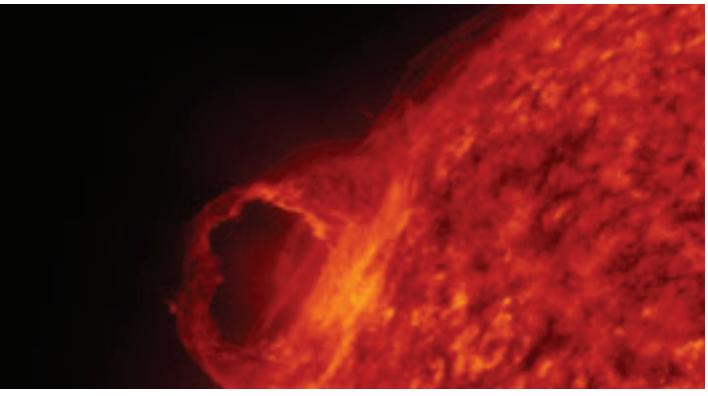
EELV was once touted as a kind of paradigm shift for DOD. It was supposed to greatly ease budgetary pressures for the Pentagon and give U.S. private industry a competitive edge in the launch services market. It did neither. Our view is that the experience proved to be a net loss for the U.S. launch industry.

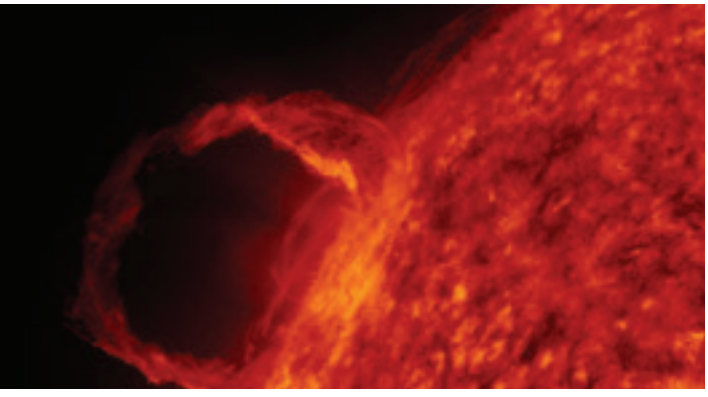
One of the main challenges for Orbital Sciences, SpaceX and other private launch companies will be to avoid being lulled into a similar trap of market complacency. One of the main challenges for NASA will be not to assume that, because it will no longer own and operate its own human spaceflight vehicle, it can easily avoid continuing to dominate this segment of the space market and thereby stifle its expansion.

Marco Caceres
Teal Group







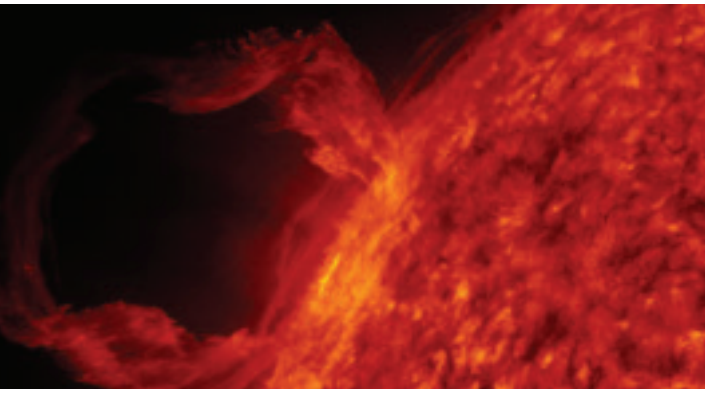


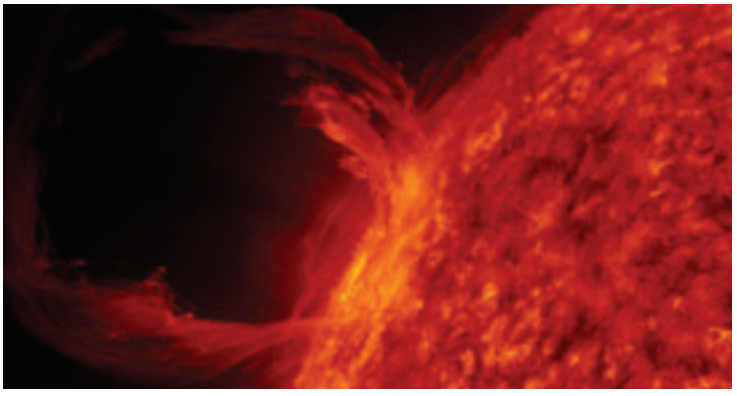
Dazzling images

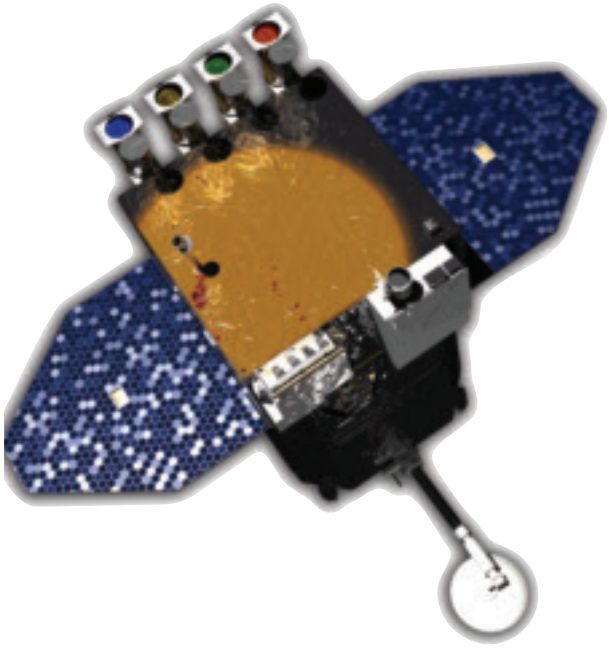
from our nearest star

The Solar Dynamics Observatory is designed to help us understand the Sun's influence on Earth and near-Earth space by studying the solar atmosphere on small scales of space and time and in many wavelengths simultaneously.

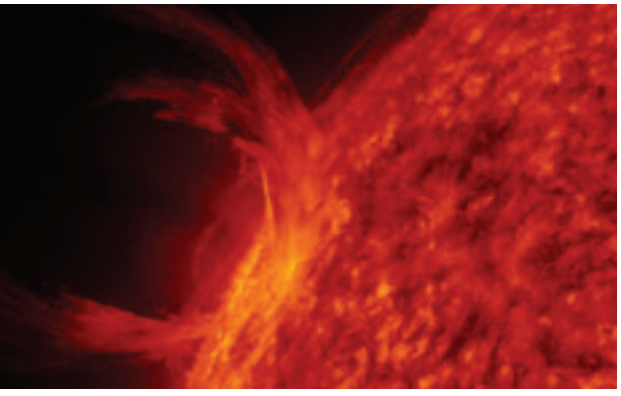
Soon after the instruments opened their doors, the Sun began performing for SDO with this beautiful prominence eruption. The Atmospheric Imaging Assembly data, from March 30, 2010, show a wavelength band that is centered around 304 Å. This extreme ultraviolet emission line is from singly ionized helium and corresponds to a temperature of approximately 50,000 C. The AIA images the solar atmosphere in multiple wavelengths to link changes in the surface to interior changes. Data includes images of the Sun in 10 wavelengths every 10 seconds. PI: Alan Title; PI Institution: Lockheed Martin Solar Astrophysics Laboratory. [Text and images courtesy NASA Goddard.]

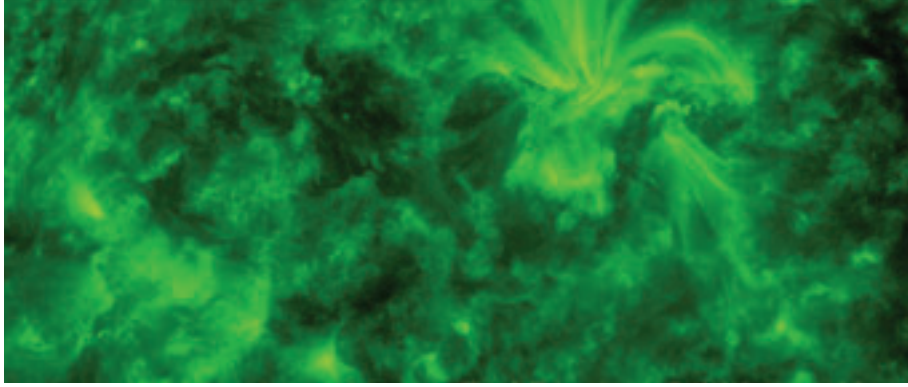


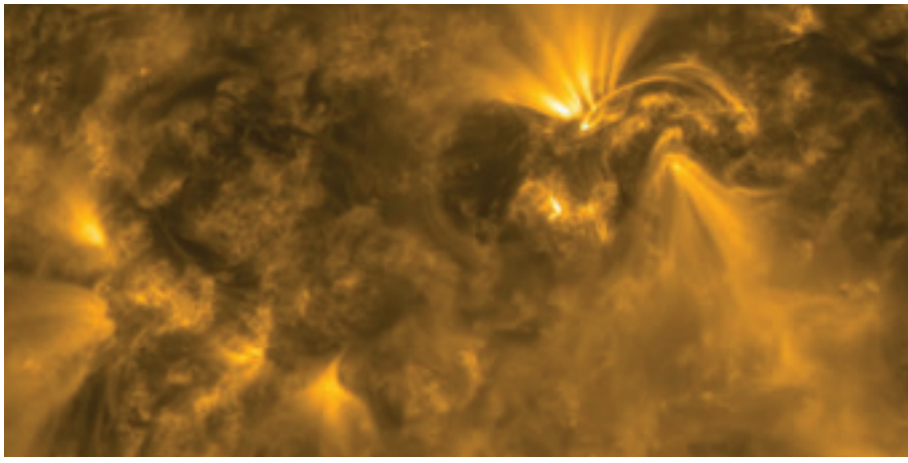


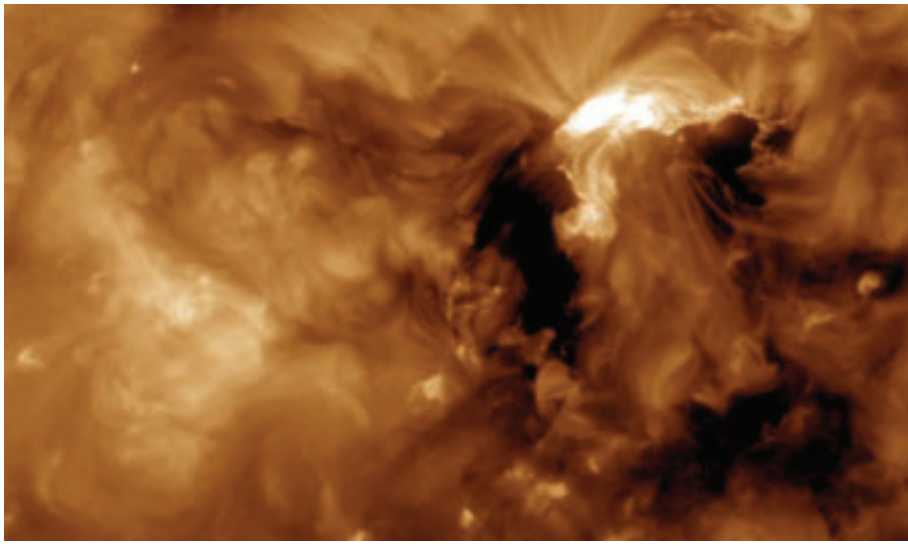


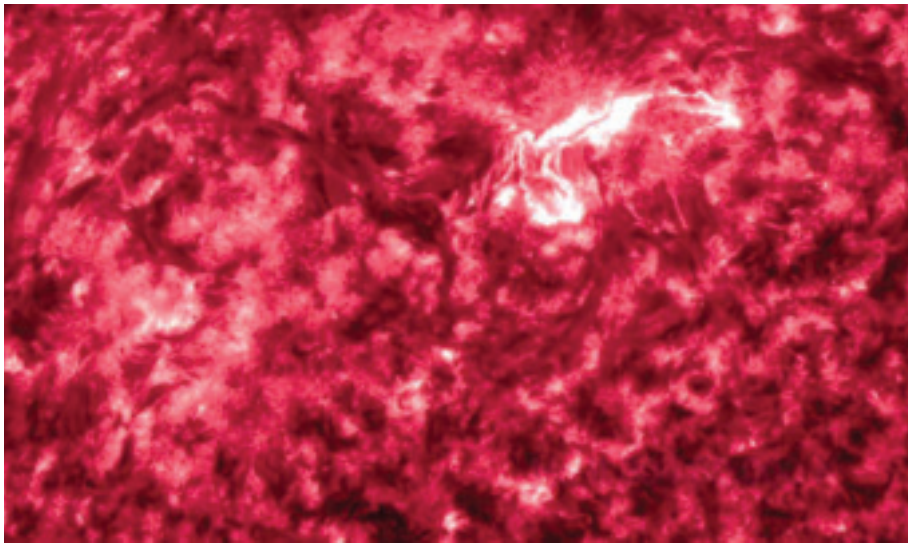
These stills from the HMI magnetic map show the Sun's magnetic field followed by four of SDO's 12 imaging wavebands. The Helioseismic and Magnetic Imager provides continual full-disk coverage at higher spatial resolution and new vector magnetogram capabilities. PI: Phil Scherrer; PI Institution: Stanford University.











Termination of Constellation is not the only drastic change proposed in the Obama administration's new space policy. A larger role for private industry, an extended life for ISS and greater emphasis on robotic and Earth monitoring missions are also in the offing. The policy is continuing to draw extremes of praise and criticism, sometimes from unexpected sources.

Momentous changes are in the making for U.S. space policy, programs and priorities. President Barack Obama's new space strategy, pegged to his proposed cancellation of NASA's Constellation manned spaceflight program, is highly controversial and may yet be modified somewhat by Congress. Even so, the agency's culture and ways of doing business will almost certainly never be the same.

The Obama space plan focuses on finding new and less expensive means of exploring space, extending NASA's responsibility for manned spaceflight to the private sector and lengthening the lifespan of the international space station. It also puts a premium on fostering commercial space transportation, developing heavy-lift propulsion technologies, preparing for scientific robotic missions and developing spacecraft for climate change observation and research.

Dimensions of the space policy and its rearrangement of priorities and financial resources are revealed in the administration's proposed $19-billion NASA budget for FY11, a 1.5% increase over funding for the current fiscal year. That budget includes substantial additional funding to nurture new technologies for future human space exploration beyond LEO, an endeavor that ended

by James W. Canan
Contributing writer

Paradigm shift
IN U.S. SPACE POLICY

with the last Apollo Moon landing in 1972. It also accentuates Earth observation and planetary science programs.

Intense reactions

From the beginning, the Obama space initiative evoked both strong support and stern criticism. Proponents hailed it as an innovative, realistic, promising and affordable approach to human spaceflight and exploration. Critics deplored it as both too radical and dangerously dismissive of NASA's time-tested priorities and practices for manned missions. They also cast it as the beginning of the end for U.S. leadership in space, saying it would reduce NASA to little more than a technology development and demonstration agency.

The new proposal has been strenuously debated in Congress and elsewhere. Scrapping Constellation, its big sticking point, cannot be done without congressional approval. The U.S. has invested $9 billion in Constellation, and the economic and political stakes in the program are high.

NASA implemented the Constellation program in 2004 to meet the Bush administration's stated goals of transporting U.S. astronauts back to the Moon and paving the way for future missions much deeper into space, perhaps to Mars and the asteroid belt. Abandoning the program will end the development of its Ares I and Ares V rockets, Orion crew exploration vehicle and Altair lunar lander.

This will leave NASA with no new man-rated spacecraft of its own for a long time to come—maybe permanently—and compels the U.S. to turn to commercial companies to take astronauts into orbit for the time being, and perhaps indefinitely.

The space shuttles, which have been NASA's only manned launch vehicles for more than 30 years, would be retired upon

Obama takes aim at asteroids, Mars...and critics

After the hue and cry that greeted President Barack Obama's initial presentation of his plan for early 21st-century human exploration, a conference was hastily assembled to offer some details and perhaps calm some fears. The president's plan, which he explained in some detail in an April 15 speech at Kennedy Space Center, is a gamble that puts U.S. space leadership, and the careers of thousands of aerospace engineers and workers afloat—somewhere between the Moon and Manhattan-sized asteroids that are the new stepping stones to Mars.

Nine previous U.S. presidents supported in principle use of the Moon as the staging point for an evolutionary human push deeper into the solar system. But neither past presidents nor the Congress acted decisively enough for a sustained program. Obama is abandoning the Moon as an evolutionary proving ground for much more complex Mars missions. His strategy trades the Moon for quicker, more revolutionary human exploration of potentially threatening asteroids, as well as access to Lagrangian (L) points about 1 million miles from Earth. Missions to both would be launched from NASA Kennedy by 2025. L points are increasingly important because spacecraft parked there remain basically stationary relative to the Earth, Sun and Moon.

The president announced several spacecraft and launcher goals:

*•**Orion Lite:** Lockheed Martin development of Orion spacecraft will continue, but with initial versions planned for use as crew rescue vehicles, parked at the ISS. They would be launched unmanned by Atlas V or Delta IV EELVs. The craft will be built at Kennedy, which will become much more of a development site for numerous technologies rather than just a launch facility. Use of Orion as an ISS lifeboat would negate the need for U.S. astronauts to rely on Russian Soyuz craft for reentry in an emergency. Several will be built to enable periodic change-out and refurbishment. Continued development also makes Orion available for future upgrade to a crew launcher, as originally intended in the Constellation program. That means that NASA will lead development of a vehicle that could possibly be used in place of commercial spacecraft, should commercial development fall dangerously behind. Obama also said Orion could be one element of spacecraft configured specifically for trips to asteroids or L points. Once stationkeeping with an asteroid, astronauts would only need to use simple manned maneuvering units to fly over to land on it.*

*•**ISS transportation node:** Obama did not say it specifically, but his vision for Orion Lite includes using the ISS as an implicit transportation node for deep space missions. Some or all manned missions would stop at the ISS, then depart for distant destinations.*

*•**Heavy-lift launch vehicle:** Obama said that to replace the canceled Ares V, NASA will finalize the design of a new heavy-lift launch vehicle no later than 2015, "and begin to build it." He added, I want everybody to understand: That is at least two years earlier than previously planned—and that is conservative, given that the previous program was behind schedule and over budget." More than $3 billion is being poured immediately into new heavy- lift options. That will be to develop "a vehicle to efficiently send into orbit the crew capsules, propulsion systems and large quantities of supplies needed to reach deep space," Obama said. "In developing this new vehicle, we will not only look at revising or modifying older models; we want to look at new designs, new materials, new technologies that will transform not just where we can go but what we can do when we get there."*

*•**Kennedy modernization:** An additional $3 billion will be pumped into the center over the next five years to modernize the infrastructure.*

The shift from the Moon to asteroids was made because the administration believes a return to the Moon would not have driven technology. It would have been an evolutionary program, and Obama is willing to trade a longer post-shuttle flight gap for more advanced technology development leading to the new targets. This shift is the single largest shakeup in American space planning history. Early planetary scientists believed that lunar samples would provide major insight into the formation of the solar system. That proved not to be the case, although Moon rocks have provided major new information on the formation of the Earth/Moon system.

The science community now believes that sampling asteroids can help solve major questions about the solar system. Exploring and sampling both solid-body and much less dense "rubble pile" asteroids can also be "the ultimate 'green' missions," providing critical information about how to divert asteroids threatening life on Earth. Accessible asteroids and L points are about three to four times farther away than the Moon, requiring new life support systems to support a crew for several weeks, a significant step toward even more capable systems to support multimonth missions to Mars.

The administration does not want the future space program to become "Moon stuck"—bogged down with a major manned lunar infrastructure, much like the shuttle and space station development have kept astronauts trapped in LEO for 35 years. In addition to advanced environmental systems, the administration believes the asteroid/Lagrangian goal will enable faster development of propulsion technologies that would enable U.S. astronauts to begin asteroid and L point missions by 2025, and missions to Martian orbit with landings on its moons Phobos and Demos by the mid 2030s. There is nothing in the Obama strategy that puts the Moon off limits, and indeed some lunar orbit missions will likely be flown by the early 2020s to prove out asteroid mission spacecraft while only three days from Earth instead of three weeks of travel time from an asteroid.

Manned Mars missions in the latter 2030s and after 2040 would be far more complicated, with heavier spacecraft that would dive through the Martian atmosphere for landing. After surface explorations lasting weeks or months those manned vehicles would climb back out of the Martian gravity well for return to Earth, stopping possibly in Martian or Earth orbit. There will be an increased number of unmanned Martian precursor missions such as more advanced rovers, and by later this decade and in the 2020s unmanned sample return flights.

Obama aimed part of his message directly at congressional delegations that, without regard to new exploration strategy, seek to extend the Constellation contracts now canceled by the customer—NASA. He said, "There is a sense that people in Washington—driven sometimes less by vision than by politics—have for years neglected NASA's mission and undermined the work of the professionals who fulfill it.

"Some have had harsh words for the decisions we've made, including some individuals who I've got enormous respect and admiration for," he continued, referring in part to astronauts and shuttle designers who spoke against his changes. "But what I hope is that everybody will take a look at what we are planning, consider the details of what we've laid out, and see the merits as I've described them. The bottom line is nobody is more committed to manned spaceflight, to human exploration of space than I am. But we've got to do it in a smart way, and we can't just keep on doing the same old things that we've been doing and thinking that somehow is going to get us to where we want to go."

Craig Covault
Kennedy Space Center

completion of three more flights scheduled through this year. Once that happens, NASA will have to rent space on Russian Soyuz spacecraft to ferry U.S. astronauts to the ISS, an inevitable turn of events that rankles many U.S. space officials and aficionados. Obama proposes to give the ISS a new lease on life, committing the U.S. to extending its operational duration through 2020.

The new NASA strategy marks a sharp break with the standard practice of the past, in which the government funded, controlled and conducted all manned space launches and operations. The change signals "the entrance of the entrepreneurial mindset" into the space arena, and has the potential to create thousands of high-tech jobs while providing affordable access to space, according to NASA Administrator Charles Bolden.

Review findings

The U.S. space initiative is derived from the findings of the 10-member blue-ribbon Review of U.S. Human Spaceflight Plans Committee—known as the Augustine committee. John Holdren, director of the White House Office of Science and Technology Policy, assembled the panel early last year to review NASA's programs and assess its future. Chaired by former Lockheed Martin CEO Norman Augustine, the committee concluded that the Constellation program was badly underfunded, that its key milestones were slipping, and that it would not succeed in resuming U.S. manned spaceflight to the Moon or anywhere else at an affordable cost or within a reasonable timeframe.

The Augustine panel estimated that Constellation's heavy-lift Ares V rocket, designed to launch astronauts to the Moon, would not be available until 2028 or 2030, and that "there are insufficient funds to develop the lunar lander and lunar surface systems until well into the 2030s, if ever." The committee report asserted that "whatever space program is ultimately selected, it must be matched with the resources needed for its execution."

Industry's role

Amid the debate over the plan, one thing seems certain: The U.S. space program sooner or later will require launch vehicles capable of carrying human crews into and beyond LEO. The fundamental question is whether those vehicles should be built under the auspices of the government or private industry—or both.

Speaking shortly after the plan's release, Bolden emphasized that NASA's long-time launch contractors, such as Boeing and Lockheed Martin and their joint venture United Launch Alliance (ULA), will be eligible to take part in the privatized space operations of the future, along with such relative newcomers as Space Exploration Technologies (SpaceX), Orbital Sciences, Sierra Nevada and others.

The NASA administrator said there is a misconception that the safety of the crews of private-sector spacecraft will be jeopardized in the hands of untested space launch companies. On the contrary, he declared, NASA's commercial partners in human spaceflight will be the same as those already entrusted with "transporting our multibillion-dollar satellites."

Work on Ares I will be terminated, despite one successful test flight.

The Augustine panel estimated that the heavy-lift Ares V rocket would not be available until 2028 or 2030.

"Commercial launch vehicles have for years carried all U.S. military and commercial satellites and most NASA satellites to orbit," Bolden said. And just as it did 50 years ago in upgrading existing rockets for the pioneering Gemini orbital spaceflight program, "NASA will set standards and processes to ensure that these commercially built and operated crew vehicles are safe," he asserted.

The NASA FY11 budget provides $6 billion for continued development of commercial space transportation. It also includes $3.1 billion through FY15 to develop new engines, materials and propellants for heavy-lift launchers to take astronauts beyond LEO. In the same time frame, roughly the same level of funding is projected for scouting possible space exploration targets and identifying their hazards and resources for human habitation. Programs to develop advanced communications, sensors and robotics are slated to receive $4.9 billion.

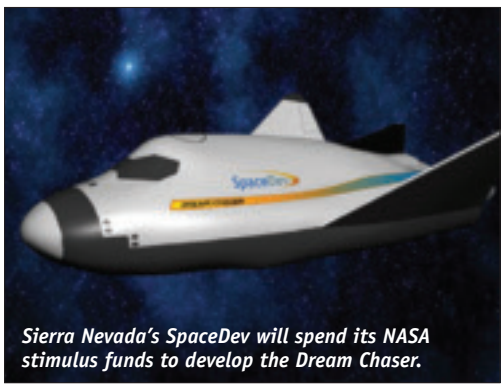
Budget increases and cuts

The new space plan marks the beginning of NASA's "transformative technology initiative," an endeavor slated to receive $7.8 billion over the next five years. Its goal is to develop and demonstrate spaceflight technologies that presumably will cut the costs and increase the capabilities of future space systems—rendezvous and docking, orbital fuel storage and life support are examples.

NASA's Exploration Systems Directorate takes a big hit. Its sharply reduced and redirected funding is a major issue in the debate over the Obama space policy. The directorate was created in 2004 to follow through on the Bush administration's plan to send U.S. astronauts back to the Moon and then on to Mars. It was to have received $5.5 billion in the coming fiscal year to continue developing the Ares I and Ares V rockets and the Orion vehicle.

The new budget cuts the directorate's funding to $4.26 billion. Almost half that—nearly $2 billion—would be spent on closing out the Constellation program. An additional $600 million is allocated to continue the closeout in FY12. Moreover, NASA is requesting permission from Congress to divert some of the directorate's current funding to begin phasing out Constellation in this fiscal year.

NASA's Science Missions Directorate gets a hefty 11% funding increase in the new budget, to a level of $5 billion. Most of the $512 million in additional funds is allocated to the directorate's Earth Science Division. The agency's Planetary Science Division also receives an 11% increase to $1.485 billion, but the division's astrophysics budget, which funds the Hubble Space Telescope and other programs, is slightly cut.



Sierra Nevada's SpaceDev will spend its NASA stimulus funds to develop the Dream Chaser.

Stimulus contracts

Along with its new strategy and budget, the agency announced contract awards totaling $50 million to five companies under the economic stimulus package provided by the American Recovery and Reinvestment Act of 2009. The companies—Boeing, Blue Origin, ULA, Sierra Nevada and Paragon Space Development—will develop crew module and safety concepts and demonstrate new technologies for future commercial support of human spaceflight.

Boeing, NASA's teammate in developing the ISS, is designing a module to carry crew and cargo to the station and to commercially built and operated orbital stations aboard various launch vehicles, including the SpaceX Falcon 9 and the ULA Delta IV and Atlas V. Boeing's principal partner in the crew capsule project is Bigelow Aerospace, which is independently developing and testing three- and seven-person Sundancer space habitats.

Sierra Nevada will spend its NASA stimulus funds on development of its Dream Chaser commercial crew taxi, a derivative of the HL-20 space vehicle that NASA conceived many years ago to rescue ISS crews. Sierra Nevada is redesigning the HL-20 for launch as a lifting body aboard an Atlas V rocket and carrying a crew of up to seven astronauts bound for the ISS or other space stations.

Orbital Sciences and SpaceX, among the forerunners in creating private-sector space enterprises, are on the leading edge of commercial crew-capsule development, with their respective Cygnus and Dragon capsules already in the works. Both projects have made use of NASA's commercial orbital transportation services funding, which NASA plans to

increase by $300 million in FY11 to keep Orbital Sciences and SpaceX on schedule to deliver cargo to the ISS next year under previously awarded contracts with the agency.

Expanding opportunities

The Augustine Committee's 2009 report took note of the "burgeoning commercial space industry" in the U.S., and declared that "if we craft a space architecture to provide opportunities to this industry, there is the potential—not without risk—that the costs to the government would be reduced."

As he unveiled NASA's new budget and rearranged priorities in February, Bolden, a former astronaut, cited the Augustine panel's findings as validation of NASA's proposed reorientation, and asserted: "The truth is that we were not in a path to get back on the Moon's surface, and as we focused so much of our effort and funding on just getting to the Moon, we were neglecting investments in the key technologies that would be required to go beyond."

Rid of the Constellation program, NASA will have greater resources and be in better position to explore the cosmos, develop innovative technologies, foster commercial partnerships and enhance human understanding of our planet by flying Earth-observation systems aboard the ISS, Bolden claimed. NASA will use the station as a testbed for future exploration technologies, he said.

"All kinds of educators, colleges, science institutions and other government agencies will be using the ISS for research," he added. "There's so much we need to know before we can venture safely out of low Earth orbit for the long term. We're going to address practical medical questions about astronaut bone density and the effects of radiation—how we can reach destinations sooner to mitigate the effects on space travelers of long journeys."

Opposing views

The new strategy was widely endorsed in both government and private circles by such prominent figures as Holdren, Augustine and former lunar astronaut Buzz Aldrin. But it drew criticism from previous NASA administrator Michael Griffin and segments of the space launch industry, and from members of Congress from states with high stakes in the Constellation program.

Griffin, who backed the Constellation program while at NASA, was widely quoted in his opposition to the administration's strategy. He contended that it puts the U.S. "on a path

Orbital Sciences' Cygnus (top) and SpaceX's Dragon crew capsules are already in the works, making use of NASA's COTS funding.

that can't work," and that it means the nation is "not going to be a significant player in human spaceflight for the foreseeable future."

Griffin noted that during his tenure as administrator he favored NASA's funding of cargo-carrying spaceflights by commercial companies. But he said that commercial firms are not yet ready for the risky venture of launching humans into space.

This viewpoint is disputed by champions of the new plan. Bolden noted that commercial companies already launch all U.S. communications, weather, imaging, navigation and intelligence satellites "upon which our lives depend at home and abroad." He promised that the commercially built space vehicles "will be safe." John Gedmark, executive director of the Commercial Spaceflight Federation, declared, "If the Pentagon can trust private industry with this responsibility, we think NASA can too."

Salvage attempt?

Some critics of NASA's big changes insist that the Constellation program is not too far off track and can yet be made to work. In a statement, Alliant Techsystems (ATK), the prime contractor on the first stage of the Ares I rocket, questioned "why at this time the nation would consider abandoning a program of such historic promise and capability—with so much invested." ATK claimed that the Ares development program "is meeting all major milestones" and that "NASA and its industry partners have made significant progress in Constellation's development, culminating in the successful Ares I-X test flight."

In the speech President Obama gave on April 15 he called for a version of the Orion capsule to be parked at the ISS as an emergency escape vehicle.

The company described Ares I as "innovative" and "10 times safer than any launch vehicle in existence or on the drawing board," and stated, "To abandon Ares I as a baseline vehicle for an alternative without demonstrated capability or proven superiority (or even equivalence) is unwise and probably not cost-effective."

The company said it intends to continue developing Ares I in the hope that Congress and the administration will work together on a revised space budget that "capitalizes on the investments the nation has made in the Constellation program."

Lawmakers from Constellation states, including Florida, Alabama, Louisiana, Texas and Utah, were quick to call the space policy too radical and misguided. Notable among them were Sen. Richard Shelby (R-Ala.) and Sen. Bill Nelson (D-Fla.), chairman of the Senate Commerce Committee's science and space subcommittee.

Shelby declared that the new space budget "begins the death march for the future of U.S. human spaceflight." Nelson accused the Obama administration of shortchanging NASA by budgeting roughly $10 billion less for human spaceflight programs than the Augustine Committee had recommended spending through the next five fiscal years.

"You can't do it on the cheap," Nelson asserted at a Senate Budget Committee hearing the day after the new space policy was announced. "The problem is that you have put all the eggs in the basket of assuming that those commercial rockets are going to work, and that NASA is not going to have to spend a lot more on making sure those commercial rockets are safe for humans.

"If those commercial rockets don't work, then for the foreseeable future we're going to be relying on the Russians just to get to our space station," he continued. NASA should continue developing and testing the Ares I rocket just in case, he said.

Bolden said NASA intends to salvage the advanced technologies being nurtured in Constellation's Ares rocket programs and Orion crew vehicle, and will apply them in the development of new human spaceflight systems, including a heavy-lift rocket. Noting that the agency has begun working on a plan and timetable for transporting astronauts beyond LEO, he claimed that resistance to canceling Constellation will only serve to delay development of that plan.

The sooner Constellation is abandoned, "the sooner we're going to go to the Moon and Mars and other places," Bolden said.

Job losses, and some gains

Bolden also deplored the loss of jobs that will result from phasing out Constellation, which employs 11,500 people in 12 states—Alabama, Arizona, California, Colorado, Connecticut, Florida, Louisiana, Mississippi, Ohio, Texas, Utah and Virginia—but claimed that the administration's commercially oriented manned spaceflight strategy and the budget increases proposed for NASA in the years ahead will create many new opportunities and plentiful jobs for the industry.

"This is a good investment for America," Bolden said. "There will be jobs in propulsion, communications and other industries. Exploration programs drive innovation throughout our economy, and NASA will be leading this economic competitiveness and growth."

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ESA's Gravity Field and Steady-State Ocean Circulation Explorer satellite is yielding discoveries in the Earth's interior and what it reveals about volcanoes and earthquakes. The satellite's mission

Making the most of GOCE

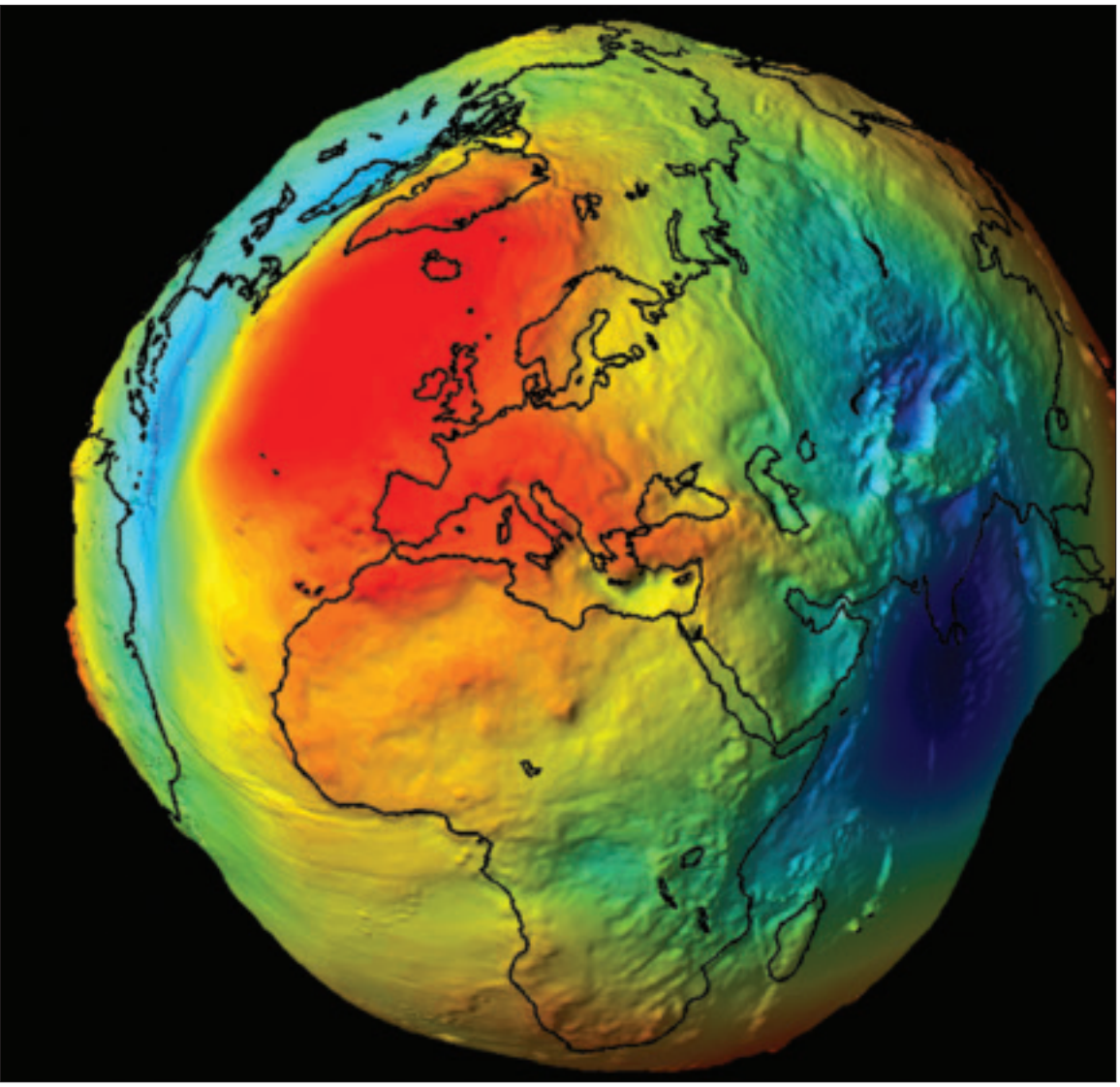
SOMETIMES A SPACE PROGRAM'S CAPABILITIES change significantly because the operating environment turns out to be markedly different from the model used in designing the mission. When this happens, it usually is bad news for all involved. A spectacular exception is ESA's GOCE (Gravity Field and Steady-State Ocean Circulation Explorer) satellite.

Launched from northern Russia on March 17, 2009, GOCE was expected to spend 20 months orbiting at the very edge of the atmosphere, studying the Earth's gravity field and its variations. Mission models had called for six months of measurements, to be followed by four months of "hibernation" while the satellite was in a period of eclipse, then six more months of measurements. ESA hoped that the mission's life might be extended enough for an additional measurement phase if on-board fuel reserves were not depleted by orbital adjustments.

But two developments have now given researchers far more time for measurements than they ever thought possible—an extremely precise initial orbital placement and discovering that the hibernation period will not be necessary. (See "GOCE adds gravity to

by **J.R. Wilson**
Contributing writer

areas ranging from ocean currents and their effects on climate to the density of is also gaining significant benefits from some surprising on-orbit conditions.



The GOCE mission is measuring high-accuracy gravity gradients and providing a global model of Earth's gravity field and of the geoid. The geoid (the surface of equal gravitational potential of a hypothetical ocean at rest) serves as the classical reference for all topographical features. The accuracy of its determination is important for surveying and geodesy, and in studies of Earth interior processes, ocean circulation, ice motion and sea-level change. Credit: ESA.

ESA's agenda," July-August 2009, page 32.)

"We have funding for the program until the end of the nominal mission, which is April 2011, but it is clear we have resources on board for a longer mission," GOCE mission manager Rune Floberghagen tells *Aerospace America*. "When we launched, we knew solar activity was low, but the type of air drag we encountered in the 280-km injection orbit was really remarkable, about a factor 4-6 less than any model we had been using.

"There are two reasons for that—one, solar activity is low, so actual air density is much less than we had designed for; second, the interaction between the satellite and the environment was different from any models we had devised. The way of modeling the upper layers of the atmosphere, whether using a thermal or a rarified gas model, suddenly was very different from what we experienced. For science, that is good, meaning we can fly the mission lower than anticipated, and the delay in launch from the original plans [May 2008] hasn't hurt us at all."

Learning to fly

The GOCE satellite relies on aerodynamic passive stabilization. Operating in an environment unlike that for which the attitude controllers were designed did cause some early problems with these devices, but the overall impact was stunningly positive.

"The first thing we had to learn was how to fly the satellite—which has a long, thin design very different from the typical 'washing machine' style—in this very much reduced air drag environment. Once we got that under control, however, it was excellent news for the mission," he says. "We have been moving steadily lower in the atmosphere as a result and currently are at about 254.9 km, which is excellent for signal-to-noise, which is better for the mission."

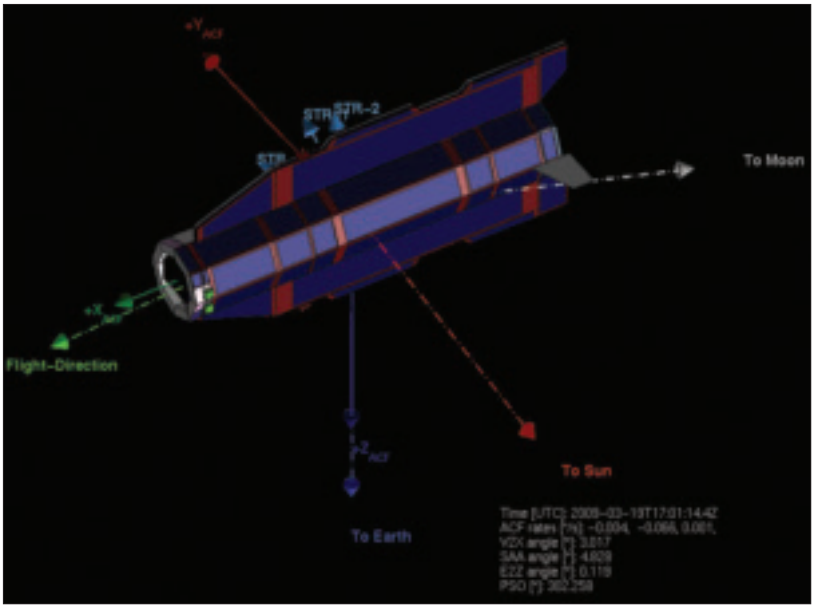
Floberghagen and his team spent the better part of the summer of 2009 "basically doing nothing much else than letting the satellite decay freely down to an altitude where the air drag is within the envelope of the ion engine—air levels between 1 and 20 millinewtons," he adds. "What we saw in the injection altitude is that for about one-third of each orbital revolution, there was basically no air at all, less than half a millinewton.

"For up to half an hour of every 90-min orbit, we had air drag well below the minimum capability of the engine, allowing it to overcompensate at a steady level of operation. The orbit altitude then increases a little and measurements become better. We could fly below 250 km, but it takes time to dive through the atmosphere, even when there is so little. We decided 979 orbital revolutions in 61 days was a good orbit with decent noise and excellent sampling capability, so we stopped the decay and started the science phase," Floberghagen says.

To ensure constant sampling characteristics for the gravity field, the satellite's altitude is actively maintained to within ±50 m, far more precise than the 1-km altitude control requirements in the mission plan. In reality, Floberghagen says, they have been able to keep the satellite within a couple of meters of its target altitude on a steady basis.

"That means the system is working in a predictable way. The ion propulsion system is coupled to a controller using satellite instruments to measure all the forces that act on the spacecraft. A control signal then goes to the engine, so the system works in a closed loop," he explains. "So the altitude goes up or down depending on whether the bias of the system is plus or minus.

"Our drag-free and attitude control system does not only maintain the altitude, but makes sure it is free from any environmental perturbations, so the sensor flies as if it is in a complete vacuum. And the system has reduced this very low air drag by at least three orders of magnitude. In fact, the drag-free system is operating at least one order of magnitude better than spec, so even as a technology demonstrator, GOCE is a fabulous success."



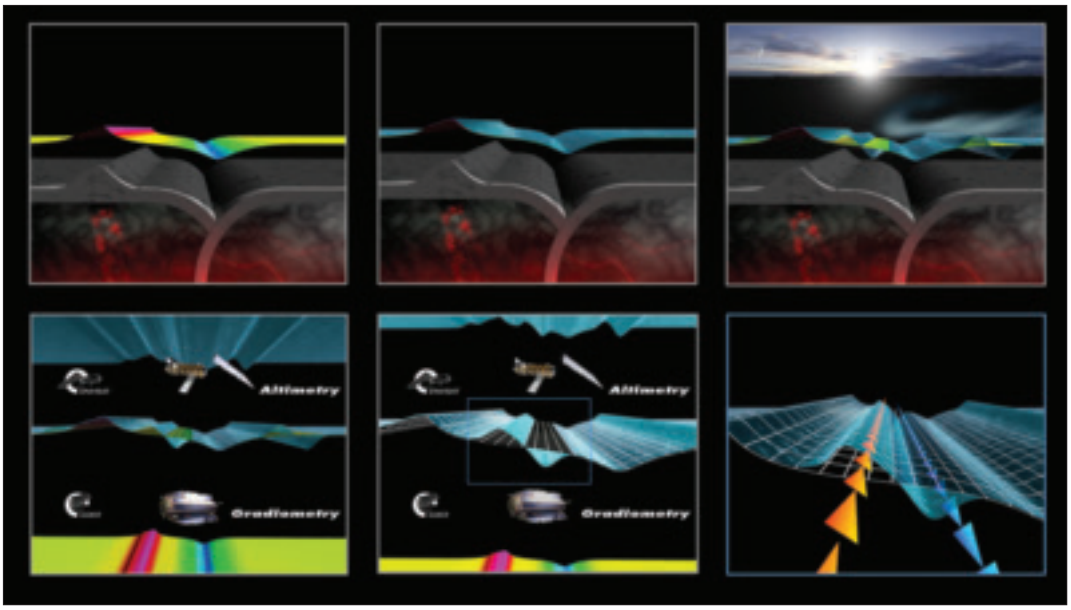
This screenshot was taken from the Flight Dynamics system and shows GOCE oriented in orbit after achieving Fine Pointing Mode. The two green arrows pointing to the left are aligned, indicating that the spacecraft is properly oriented along the direction of flight, thus minimizing drag. Credit: ESA.

A matter of gravity

The technologies used in the satellite are not the only successes, however. Floberghagen says the data they have collected in just a few months of operation have greatly expanded knowledge of the Earth's gravity. Once a complete plot has been created, it will have implications for everything from bridge construction to space launch sites.

"GOCE sees geophysical phenomena that have hitherto been hidden in previous gravity field measurements. They constitute the proof that GOCE data will definitely set a new standard in the modeling of the gravity field—and therefore in the use of gravity field models in all related areas of the geophysical sciences," he says.

"The big number-crunching job that lies ahead of us is to turn these 'maps' of measurements into a gravity field model showing the geoid or, indeed, the value of '*g*' everywhere on Earth." (The geoid is the irregular gravity field that shapes a virtual surface at mean sea level.) "This will be done in the coming few months. Presentation of our first grav-



Density variations in the Earth's crust are an important factor in shaping the geoid. External forces such as the wind cause the actual sea surface to deviate from the geoid. The combination of sea-surface height mapped by altimeters and the knowledge of the precise ocean geoid will improve our understanding of surface currents.
Credits: ESA - AOES Medialab.

ity field model is expected in June."

The initial months of calibrated measurements have followed predicted existing global gravity field models, but also have shown high spatial resolution variations, he says. The amount of variation depends on the area being observed; those already well surveyed using gravitometers on the ground or airborne data show strong correspondence, and regions not as well surveyed show greater differences, resulting in models based on previously imprecise data.

"Now we are trying to use these measurements to determine the underlying force field parameters and the geoid. That is now just getting started, but we are confident the results will be quite spectacular," Floberghagen predicts. "So far nothing hugely unusual has been seen, although we have seen things moving around a bit with respect to previous models, on a spatial scale of a few hundred kilometers, not really that small.

"But that could be the result of our initial data processing, or varying rock densities, or what is inside those rocks. We really need to take a close look at all those things before saying anything definitive. There are high-frequency spatial variations we will be investigating one by one, but it is a bit early to draw any conclusions. In six months we will know much more," he continues.

Keeping quiet

Not having to put the spacecraft into hibernation for four months at the end of each measurement cycle means the satellite can operate in full measurement mode throughout the life of the mission.

"Of course, while traveling through the eclipse, we will have to understand and deal with temperature variations, because when the satellite goes from full sunlight into complete darkness and back again, there may be some thermalastic results. You could have small amounts of stress or buckling of the solar panel that would produce small vibrations—micrometer-per-second acceleration," notes Floberghagen. "If you have a sheet of thermal insulator about 5x5 cm and it moves a millimeter at 1 *g*, you would induce acceleration on the satellite by six orders of magnitude above the sensitivity of the instruments.

"So it is of paramount importance that the environment aboard the satellite is extremely quiet, which is why we have no moving parts and attitude control is done by magnetic torquers. There are lots of factors in place to reduce any movement or noise, but we cannot exclude some response in the structure of the satellite and main instruments to these [temperature] variations. However, these effects so far have been few and far apart, so we don't believe we will be much hampered by them. Which means not only do we have the power to operate through the

"Based on careful estimates, we now believe we have enough resources to keep the mission flying for five years or so."
Rune Floberghagen, GOCE mission manager, ESA

GOCE will significantly advance our understanding of the physics and dynamics of the Earth's interior such as volcanism. Its detailed mapping along with seismic data is expected to shed new light on the processes causing earthquakes and volcanic activity and potentially lead to an improvement in the prediction of such events.

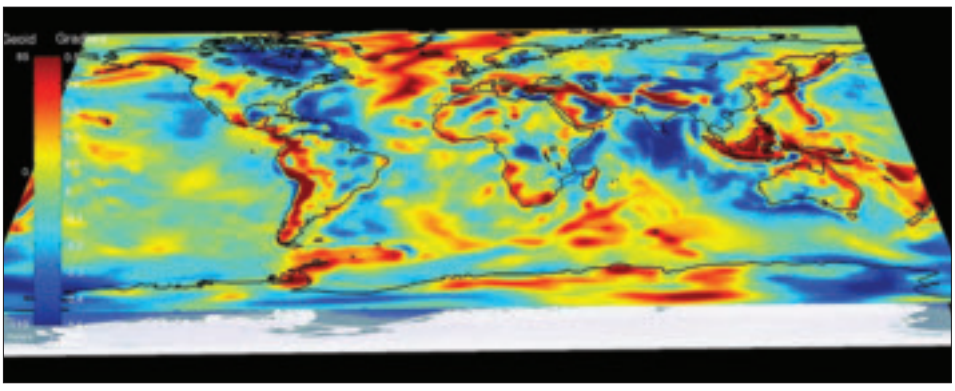
eclipse phase, we also believe the measurements, if not exactly as accurate as during the normal phase, still will be excellent."

Asking the right questions

With only a few months of measurements completed, it is still too early for GOCE to begin addressing some of the major questions scientists hope to examine. These range from using a uniform, global measurement of sea levels for studying ocean currents and thus improving climate models to providing more precise information about Earth's interior, from magma flows to tectonic movement, which could give geophysicists greater knowledge of volcanoes and earthquakes.

"We believe we will be able to meet all the original objectives of the mission. What that means in terms of how well we can measure cubic liters or kilometers of water circulating in specific areas of the oceans, we haven't gotten that far yet. It will be at least a year longer before we can begin doing that,"says Floberghagen.

GOCE's final gravity map and model of the geoid will provide well-defined data products that will be instrumental in advancing science and applications in a broad range of disciplines from geodesy, geophysics and surveying to oceanography and sea-level research. Credit: ESA.



"But when we look at the mission and performance results so far, we don't have to filter the data to get rid of striping effects or anything; it is all straight out of the box. If that also is the case later on for the gravity fields and oceanographers, it will truly be successful. But you have to gradually build a picture and do a lot of number crunching before you actually understand what all those pixels mean."

Studying the oceans—and below…

Outside of its demonstration of new methods of construction, propulsion, attitude control and edge-of-the-atmosphere flight, determining the impact of gravity variations on ocean currents remains the area in which GOCE is expected to have the greatest scientific impact. That has become even more important in light of new controversies surrounding the legitimacy of past global warming research and models.

"Given the whole debate about climate change, a uniform height system for the world, based on gravity and a uniform-quality gravity field, will allow us to revisit all the tidal records from around the globe—for the past 200 years in many places—and study sea-level rise and climate change as it impacted ocean height, in a way that has not been possible before," Floberghagen points out. "However, the data GOCE provides must be combined with other data sources to draw any meaningful conclusions with regard to climate.

"For example, we provide a reference service on ocean levels and deviations. But you need to reprocess 20 years of altimeter readings using the new data from GOCE to better determine ocean behavior during that period. Oceans truly are the planet's climate regulators, with most heat transferred through atmosphere-ocean interaction. But we need to determine the geoid, reprocess all the altimeter sets, assimilate that into ocean models and then into climate models. So we can't just measure gravity fields for a couple of months and then declare we have new knowledge about climate."

The scientific interest in GOCE's results extends far beyond those involved in studying climate, however, including what is happening beneath the surface.

"The higher the density of the planet's core, the higher the level of gravity. If density distribution were regular, we would not be able to see the differences between various layers simply from looking at surface

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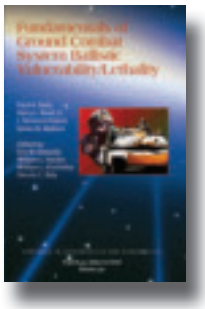

While the focus of this book is on ground combat system vulnerability, many of the principles, methodologies, and tools discussed are also applicable to the air and sea system communities.

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data. However, if the core deviates significantly from regular distribution, that would influence Earth's rotation—and there is a direct relationship between Earth rotation and gravity," he says.

"But more important for gravity is what happens closer to the crust, such as the mantle and temporal variations. So aside from the mean value of gravity, which is largely determined by the heavier material in the Earth's core, the variations are the result of things that happen closer to the surface. Which is why we can see plate tectonic changes in the gravity data, for example."

Having GOCE in orbit and making measurements for at least five years, rather than the originally planned 20 months, also will provide greater opportunities to measure, in real time, the impact of any future major geological events. The Sumatra earthquake in 2005, for example, led to a vertical displacement of several meters in a large section of the ocean floor. The result, Floberghagen says, was a measurable change in the Earth's rotation—the length of a day.

"Even an instant phenomenon, such as an earthquake, in geological timescales, can influence the Earth's rotation speed. And if something like that happens during the lifetime of the GOCE program, we certainly could see and measure that in our data," he notes. "A theory based on such data from a big event and applied to events that happened hundreds or millions of years ago would not be completely out of reality, but it would be difficult to put truly quantitative data on that.

"We're trying to combine all the information we can get, but looking inside the Earth is pretty hard to do. You try to combine gravity, magnetic field information, data on seismic wave travel times and so on to deduce something about an event. Gravity field information adds to that, and gravity has a tendency to restrain the others. But if you know and understand better what might happen, you can better prepare yourself."

...and the air up there

A new and serendipitous mission goal is to improve scientific understanding of air density by looking at air-drag models of the thermosphere through which the satellite is flying.

"Because our data are very different from what the models predicted, we are looking at addressing air density and winds in an orbital altitude where no one else has flown," notes Floberghagen. "We should not just leave what we've found on that in the drawer, but make it available to build better models of the atmosphere at this altitude. That is a byproduct we are 90% sure we can produce in the next couple of years."

That element not only has increased the potential value of the GOCE mission, but also is expected to impact the entire family of European Earth explorer satellites, of which GOCE is a member. Six essentially single-issue satellites are being built to examine fundamental Earth science, from gravity to clouds and aerosols, thermal issues, the magnetic field, sea ice and so on. A seventh satellite is under study, and ESA has called for ideas for an eighth.

An accurate model of the geoid will advance our understanding global ocean circulation patterns and sea-level rise.

Deciding what's next

"One discussion now running within ESA is what to do with the knowledge we are gaining from GOCE and other early satellites. We have two branches of Earth observation missions in ESA: The workhorses, such as Global Monitoring for the Environment and Security, which are closely linked to the activities of the EU and the theme of the Earth observation mission; the other is doing things that have never been done before, more along the lines of invention and exploration," he explains. "But after we have done the first generation of explorers, then what?

"In Europe, you can propose to build another Earth explorer, addressing new elements learned from the first. But is that enough? There may be follow-on missions arising from

different satellites. For example, an operations agency might be interested in picking up the torch to do weather forecasting because of information gathered from a first-generation satellite, so discussions with operating agencies are being held on all the Earth explorer satellites. But you also have very scientific elements, where it might not be possible to fly a next-gen immediately after the first, because the first generation already was pushing the limits of technology. At this point, we really don't know what may arise in that area."

In addition to processing information this satellite is gathering, therefore, the GOCE team also must begin putting together a clear and precise report on what has been learned in terms of technological challenges to building, launching and flying the satellite, whether it was worth the investment and whether future missions along the same line should be considered. Such evaluations also could significantly impact the future of international cooperation and new joint missions.

"It has been a great decade for geopotential research, from GRACE [Gravity Recovery And Climate Experiment, a five-year, twin-satellite joint effort by NASA and the German space agency] to GOCE. Gravity field missions have the potential of measuring variations in the Earth's mass, whether in time or space, and people want to capitalize on that and build a platform to monitor this over longer time periods in the future," Flobergh agen says. "In the U.S., a GRACE follow-on is part of Tier 3 of NASA's decadal survey, and in Europe there is significant pressure for a next generation of gravity field missions.

"The idea would be to combine the capabilities of GRACE, in terms of temporal resolution, with GOCE, in terms of spatial resolution, to measure variations in the Earth system, from ground water changes to ice floes to temperature variations. We don't know what will be the ultimate conclusion of all this, but international cooperation for the next-generation missions certainly is possible, given the technology, scientific expertise and interest on both sides of the Atlantic."

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Airborne laser shootdown

Defying the odds

Recent successful tests of the Airborne Laser Test Bed (ALTB) have demonstrated the technology's potential to change the future of warfare, even according to critics. Yet DOD has defunded a second aircraft, calling the concept "fatally flawed." ALTB proponents argue that the program is vital to maintaining the nation's edge, both on the battlefield and in the technology workforce.

by J.R. Wilson
Contributing writer

When a cutting-edge technology program finally reaches the stage of real-world testing—and performs as advertised—those involved typically are exuberant, looking forward with great anticipation to advancing the technology and ultimately fielding the system. For the Missile Defense Agency's Airborne Laser Test Bed (ALTB) team, however, the prevailing emotion was frustration.

During tests in January and February, the ALTB (formerly ABL) became the first aircraft-mounted directed-energy weapon to successfully shoot down real missiles during the critical boost phase. The ALTB team consisted of Boeing Defense, Space & Security, Lockheed Martin Space Systems and Northrop Grumman Aerospace Systems.

Scoring fast

The first test, against a high-power MARTI (missile alternative range target instrument), sought to demonstrate that the ALTB's laser could focus a tight beam on a small target area of a fast-moving rocket for a long enough time to destroy it.

"That test was very successful and gave us the confidence to put our beam within centimeters of the surface of a missile going upwards of Mach 6—find it, detect it, precisely put our beam within centimeters of where we wanted it and score," Boeing vice president and ALTB program director Michael Rinn tells *Aerospace America*.

"We were able to look at the size and intensity of the beam and how much it was moving as we held it on this rapidly accelerating target. We took all the data and turned the

On July 21, 2009, at Edwards AFB, the Airborne Laser's first chemical flight test demonstrated the safe flow of chemicals through all laser systems.

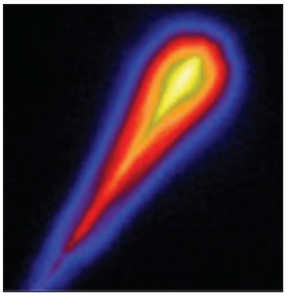
system around on 3 February and, on our first shot, we killed a Terrier Black Brant solid rocket—and did so very rapidly."

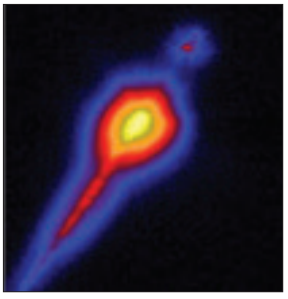
MDA chose not to release that information for another week, he adds, when the goal would be to use the ALTB's chemical oxygen iodine laser (COIL) to destroy a boosting missile.

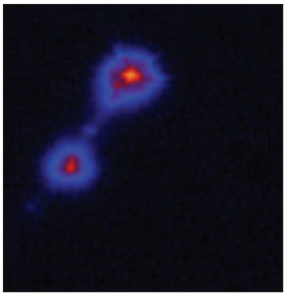
"On 11 February, seven days later, we engaged a liquid-fueled, no-kidding threat foreign missile and killed it in a very rapid engagement. I can't talk about the specifics, but we killed it in less than half the time we had predicted, which is a testament to the design of the system and this team's tenacity," Rinn says. "I can say it was a very quick-burning, short boost time, which was one of the more stressing tests for ABL, rather than longer burning intermediate or longer range missiles. You have to find and acquire this kind of target very quickly.

"This experiment marks the first time a laser weapon has engaged and destroyed an in-flight ballistic missile, and the first time that

Infrared image shows the ALTB (right)destoying a short-range ballistic missile.







This sequence shows a threat representative ballistic missile's breakup resulting from a high-energy laser engagement by the ALTB on February 11.

any system has accomplished it in the missile's boost phase of flight. ALTB has the highest energy laser ever fired from an aircraft and is the most powerful mobile laser device in the world."

A touchdown (but no extra point)

On that same mission, the ALTB team also was tasked with shooting down a second missile, of a different type, to prove the system is capable of quickly regenerating the laser, finding a new target and destroying it within a matter of minutes. The Terrier Black Brant again was employed for that test. What happened next initially was reported as a misalignment of the laser, which would have been a serious problem, but Rinn says that proved not to be the case.

"We were able to turn the system around quickly, switch from a liquid to a solid target, acquire, track and put high power on the side of it. We downloaded (halted) the system before we killed it, not due to an alignment issue—there was not an alignment issue, that held up very well, as designed—but a minor issue in one of our safety systems that downloaded us back to a standby level. We understand that issue, and the system is ready to go back into test. It was ready that night, actually," he says.

"This is a test bed, and we are still learning the system, the safety measures that protect the hardware. We consider it a huge success that we not only killed two missiles in seven days but were very close to killing a third missile on that second mission. Had we continued to lase, we would have killed it. It was basically just a threshold in the safety system. We've been learning about where to set these thresholds and have been very cautious in that, as we should be.

"That night, Gen. O'Reilly [Army Lt. Gen. Patrick O'Reilly, MDA's director], who was on site with the team, told them they had just scored the winning Super Bowl touchdown, but missed the extra point on the second missile. We learned a huge amount that night, and it was a big success. The entire test bed system is performing far better than we ever expected. The intensity of the COIL, the beam correction system for the atmosphere and system pointing are behaving extremely well—and repeatedly."

Muted applause

That level of success with a technology and system that had never before been attempted would normally have been cause for celebration. However, the ALTB team's reaction was muted by Secretary of Defense Robert Gates' decision—announced nearly a year earlier—not to build a second ABL aircraft, and to move the renamed ALTB from MDA to the Pentagon's director of defense research and engineering for "general research" use.

In a speech on July 16, 2009, Gates said ABL had failed to demonstrate its military value despite more than a decade of R&D and some $5 billion invested in research under MDA. He followed up by failing to allocate any specific funding for the program in the Pentagon's 2011 budget proposal.

"The program and operating concept were fatally flawed," Gates declared.

That was despite an official MDA recognition that directed energy has the potential to change the future of warfare: The agency had presented its Technology Pioneer Award to three Boeing ABL engineers and three of their government and industry teammates. Boeing, the team leader, is responsible for weapon system integration, the heavily modified 747-400F freighter and battle management, command, control, communications, computers and intelligence. Northrop Grumman Aerospace Systems designed and developed the COIL and the beacon illuminator laser, while Lockheed Martin Space Systems supplies the beam control/fire control system.

The ABL program's goal was to provide combatant commanders with a speed-of-light capability to intercept and destroy all classes of ballistic missiles while they are still in the boost phase of flight, thus ensuring that any debris—including whatever might be in the missile's warhead—would fall back on the launching force rather than hitting another nation or allied force. The program had recorded a series of successful ground and air tests in the two years leading up to the 2010 missile shootdowns.

Meeting capability goals

The ALTB team is convinced the January and February airborne tests fully demonstrated the capability goals set for the effort, meeting the criteria Rinn set out in an earlier interview with *Aerospace America* (see "Airborne laser aims at final tests," July-August 2009, page 44). At that time, he believed successful tests would show the ABL test bed aircraft itself could be ready for combat use, much as the J-STARS surveillance prototype aircraft had been deployed to Iraq during the first gulf war.

"Based on what I know of the system, I believe we will have some emergency deploy-

ment capability if the nation or our allies require it shortly after shootdown, in 2010. There are some limitations, clearly, such as logistics streams, and there is definitely more work to be done. But you would have a single ABL with some strong possibilities, similar to J-STARS during Desert Storm," he told *Aerospace America* in late 2009. "In demonstrating the capability of this system, both for boost phase and potentially alternative missions—SAMs, cruise missiles, air-to-air missiles—there will be a tremendous potential."

Air Combat Command had envisioned a fleet of seven ABL aircraft—beyond the prototypes—going into service, one per year, between 2018 and 2025.

"People have talked about directed-energy systems for decades; now we actually have a system up and running and have demonstrated directed energy gives you very, very rapid engagement timelines and the capability for precisely pointing and putting a measured force on a target. That is something unique to weapons systems developed to date," Rinn now says. "No one has ever put a directed-energy system of this magnitude and precision on an airplane before, nor accomplished what we just recently accomplished. This is an historic event.

"Basically, everything I said we were going to do [during the 2008 interview] we have done. The system was ready to shoot down at the end of 2009, but we had to wait for range time and target availability, so we were very close to what we had predicted, which is an important point for this test bed. One thing we had to do in 2009, or we would have finished even earlier, was replace six high-powered optics that were designed and installed in the turret. We discovered in February 2009 that the materials we had chosen for them years ago were not adequate and we needed to go to a single crystal silicon substrate for those critical optics."

Lockheed Martin ALTB program director Mark Johnson notes that a process of optics replacement that typically would take two years was accomplished in less than seven months, allowing the program to get back on schedule. At the same time, says Guy Renard, Johnson's opposite number at Northrop Grumman, the laser was fired over and over for months, producing high-megawatt energy levels safely and consistently.

New realities

While having achieved both programmatic and personal goals was cause for celebration, the team is working to adjust to the new realities imposed by Gates and President Obama, including a decision to shelve chemical laser technology as insufficient for battlefield use. Instead, the plan is to continue working on solid-state and hybrid lasers, such as a diode-pumped alkali laser being developed at Lawrence Livermore National Laboratory in California.

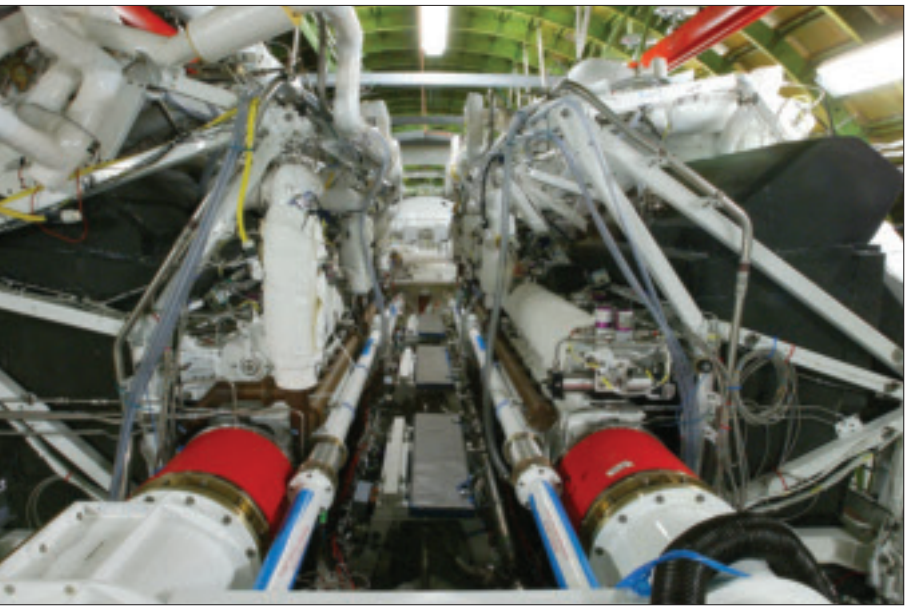
"The investment the nation has made in this directed-energy technology is a very smart investment for the future. It opens the door for a new era of directed-energy weapons that, over the coming decades, will become smaller, lighter and more efficient," Rinn says. "Most of the experts understand the state of the technology for solid-state and hybrid lasers, and those have a way to go to mature before being anywhere close to what this system already is demonstrating.

"So we are looking forward to using this test bed and system to push the envelope, to engage other types of targets—which may turn out to be more important than ballistic missiles. By that I mean showing capability in the future for this test bed to shoot aircraft at extreme range, engage surface-to-air missiles, take out sensor platforms and baseline vulnerabilities for UAVs at very great ranges. So there is a potential to take a system like the ALTB and expand it, which our nation needs to do to show where this technology is capable of going as these other technologies mature."

MDA will continue to run the program through the end of this year, and the ALTB team hopes to use remaining funds and time to further prove the technology's value—including additional missile shootdown tests.

"We are laying out plans for additional engagements this fiscal year. The system is up and ready to do those," Rinn says. "We would

The conformal window on the ABL is exposed in flight during a test over Edwards AFB. The window essentially is a very large contact lens, ground to optical specifications. Optical coatings, which make it glimmer and appear different colors, are necessary because the window is the exit point for beams from three lasers (tracking illuminator laser, beacon illuminator laser and COIL) and the entry point for laser beams designed to bounce off the target and come back to the aircraft carrying a wide range of information needed for the mission.



Northrop Grumman's COIL is comprised of six modules, which were installed inside a scrap 747 fuselage in the System Integration Lab at Edwards AFB. The view is looking down the center of the aisle formed by the V-6 configuration of the laser layout. USAF Photo.

like to begin to explore the envelope, to extend range and other variables to show the capabilities of this technology. And that's really what we're doing, so we are in sync with the agency for this year on the test plan and look forward to the additional demonstrations."

The effective range of the COIL-based ALTB was one of Gates' reasons for shutting it down. The secretary has been quoted as saying the system could only destroy missiles at a range of 135 km, far short of the 200 km in the program specifications.

"The actual performance is classified, but I can say the capabilities we showed in the first two kills exceeded our expectations. And I believe this test bed has a lot more capability that we need to show, which is the most important point," Rinn responds. "I want to keep this platform and technology going forward so the nation has the ability to see what it can do in terms of total range and different types of targets. There are a lot of different ballistic missiles that can be engaged at different ranges."

Maintaining the edge

Despite their belief in the ABL itself as a viable antimissile system, the ALTB contractors are even more concerned about the impact the effective cancellation of the program will have on the nation's ability to maintain an industrial infrastructure and workforce capable of future development in directed energy.

"If our nation wants to continue in the leadership role in directed-energy systems, as demonstrated by the ALTB, then we need to invest in the technologies and the industrial base. We are concerned about funding levels to keep these critical optical coating vendors and adaptive optics and other skills needed to integrate these systems on future platforms. The workforce is aging, and all three companies are trying to bring forward a new generation of engineers, but we are concerned about that," Rinn says.

"I know there is a tremendous amount of interest among nations capable of developing these kinds of complex technologies, and I believe there is investment there, although I can't cite any numbers.

"The advantages are obvious. If you can see it, you can hit it at the speed of light, with timelines in seconds rather than tens of minutes as with kinetic systems. There are pluses and minuses for both, and I expect them to complement each other in the coming decades. There are times when kinetic makes sense and times when directed energy has a huge advantage. And that is being recognized by other nations as well."

With the device already built, Rinn adds, even within ALTB the primary remaining area for cost-cutting is labor—the scientists and engineers who have spent so much career time moving directed energy to this point. And turning attention now to newer, less developed technologies will not provide enough jobs to attract the next generation of such specialists.

"Taking this technology to the next level clearly can solve a lot of problems in maintaining the industry base. With an R&D platform, we can only work with our supplier base on a limited number of products and quantities; we need to get into a production environment to really build and sustain that industry base," Johnson warns.

"In terms of skills, this program has a number of people who have invested a significant portion of their careers, and we do not have a significant level of program base to expand that talent. The young people we bring into Lockheed Martin to show off the technologies and programs we're working on have been very excited with what we've been doing with the ABL program. What we can do is make sure we have interesting and innovative programs for young minds to work on—and directed energy clearly is one of those."

Proving the critics wrong

As to what ALTB has accomplished thus far, the contractors acknowledge it has been a program fraught with delays and high costs, but argue that this is not unusual for a highly advanced technology test bed. And the January/February shootdowns more than justify

that expenditure of time and money, they say.

"The program had a genesis of some very bright people looking into the future and creating a path for the industry team to move out on. Every step of the way, this team has overcome obstacles, demonstrating the viability of the technologies, and has done the really difficult engineering to get this platform and system together," Johnson says.

"The critics said it wouldn't work, we couldn't get enough beam or energy on the target, the atmosphere would create too many problems. But time and time again this team has shown those critics wrong. So we are confident in moving forward on this program and pushing the envelope on what this technology can do."

To highlight the fragility of the industrial base, Renard notes that two Northrop Grumman suppliers have gone out of business since he became ALTB program director "because we could not keep them busy, having built only one." Nor does he expect those to be the last to disappear, even as the danger of missile attack grows.

"The threat will continue to grow and expand, including many nations not friendly to the U.S. There is a gap that will exist as long as the ALTB remains a test bed and is not taken further, or until we get to some future technology. We have invested in different technologies over the years and nothing has bridged the gap to an operational system," Renard concludes. "We have demonstrated the capability of this system, but the reality is that what directed energy can do to engage in the boost phase can thin the raid of any missiles launched toward the U.S. or an ally. Then other parts of missile defense can take out any remaining missiles. But the earlier you engage, the better.

"Where does this leave America? When I take off my program director hat, I see we have invested a lot in this technology; there is a gap before solid state reaches the same point, and I would like to see what we've already invested pay off and get out to the warfighters as soon as possible. It all depends on the decisions being made today within DOD relative to all their priorities."

Out of the

25 Years Ago, June 1985

June 19 Mission specialist Steven Nagel becomes the 100th American in space as a crewmember of mission 51-G on the shuttle Discovery. On the same mission, Sultan Salman Abdel Aziz al-Saud of Saudi Arabia becomes the first Arab in space. Al-Saud uses the 70-mm camera on board for photography over his country and participates in two science experiments. Arabsat A; Morelos 1, a Mexican communications satellite; and the Spartan 1 scientific satellite are launched. NASA, *Astronautics and Aeronautics*, 1985, pp. 469; *Washington Times*, June 20, 1985, p. 3A; *NASA Press Release* 85-69.

50 Years Ago, June 1960

June 3 Martin's upgraded Bullpup ASM-N-7A air-to-surface missile is successfully test fired from a Marine Corps Choctaw helicopter. D. Baker, *Flight and Flying*, p. 371.

June 6 Well-known British aviation journalist Harry Harper, who began writing on the subject in 1906, dies at 81. Harper was the "air correspondent" for the *Daily Mail* for 20 years and covered such historic events as Louis Blériot's takeoff across the English Channel and the first "air meet," at Rheims in 1909. Later, in 1956, he published a book, My Fifty Years in Flying. *The Aeroplane*, June 17, 1960, p. 727.

June 7 A Bomarc antiaircraft missile in storage at McGuire AFB, N.J., accidentally explodes and bursts into flames that destroy its 350-lb 10-kiloton nuclear warhead. But because the high-explosive igniter designed to initiate the warhead is not activated, and other safety devices work properly, there is no leakage. D. Baker, *Spaceflight and Rocketry*, p. 103.

June 8 The 59,000-lb-thrust Thiokol engine is finally installed in the X-15 rocket research aircraft (No. 3) after delays in its development. Up to now, the X-15s have used the so-called Interim Engine, consisting of two upgraded Bell X-1-type XLR-11 engines of 8,000 lb of thrust each. However, in a ground test run of the XLR-99 there is an explosion in which the aircraft is damaged, although the test pilot in the cockpit is not injured. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 124.

June 9 Semyon Alexsevich Lavoch-kin, the famous Soviet aircraft designer credited with the first Soviet supersonic jet, dies at age 59. He was graduated in 1927 from a technical school in Moscow, then served in the Red Army and in the Soviet aircraft industry. The design bureau he headed before WW II produced planes that achieved considerable success during the war, including the radial-engined La-5 and La-7. After the war he produced the La-9 to La-11, then switched to jet designs. *The Aeroplane*, June 24, 1960, p. 758.

June 20 Persian Air Services, a freight carrier, inaugurates its first DC-7C passenger service between Teheran and London. Each of its two craft, which it recently acquired from Sabena, accommodates 35 tourist-class and 12 deluxe seats. Each also carries up to 11,000 lb of freight, for which half the fuselage is blocked off. *Flight*, July 1, 1960, p. 24.

Black Knight

June 21 The second successful firing of Britain's two-stage Black Knight rocket is launched from Woomera test range in Australia. It reaches a height of 300 mi., with the impact of the nosecone at 70 mi. downrange, as planned. *Flight*, July 1, 1960, p. 5.

June 22 The Navy's Transit II-A experimental navigation satellite, plus a smaller Grab-1 or SolRad 1 satellite, are jointly launched "piggy-back" successfully from Cape Canaveral, Fla., by a Thor-Able-Star vehicle, marking the first time two active satellites are placed in orbit by a single vehicle. The SolRad, which has instruments to read solar radiation and radio noise from outer space, is a highly classified satellite with reconnaissance as its main task. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, pp. 124, 148; *Flight*, July 1, 1960, p. 5.

Robert Goddard

June 28 The Smithsonian Institution bestows its highest honor, the Langley Medal, on U.S. rocket pioneer Robert Goddard, who died in 1945. Goddard devoted most of his life to experimenting with rockets. He launched the world's first liquid-fuel rocket on March 16, 1926, and

Past

An Aerospace Chronology
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later made many other advances in rocket technology. E. Emme, ed., *Aeronautics and Astronautics 1915-60*, p. 124.

75 Years Ago, June 1935

June 6 Fairey Aviation of Hayes, Middlesex, England, introduces its Fantome as the world's fastest multigun fighter. The biplane reaches 248 mph on its first flight and carries four Browning machine guns and a 20-mm quick-firing cannon mounted in the vee of the 12-cylinder motor. The cannon fires through the hub of the airscrew. Its magazine carries 60 shells. Designed originally for the Belgian air force, the Fantome has a top speed of 270 mph. It can also carry four 22-lb bombs. *Fairey Aircraft Since 1915*, pp. 260-263.

June 13 In preparation for Pan American's transpacific service, expected to begin later this year, a Pan Am Sikorsky S-42 flying boat makes its second experimental flight from California to Honolulu. It makes the distance in 17 hr 57 min, cutting 17 min from its previous time. Two days later, Capt. Edwin C. Musick and his crew of five leave Honolulu for an additional flight of 1,323 mi. to Midway Island, one of the planned stepping stones in the projected transpacific service. This leg takes 10 hr 4 min, most of it at 6,000-8,000 ft. *Aero Digest*, July 1935, p. 104.

June 16 Two new international light seaplane records are claimed by Benjamin King, a Washington, D.C., pilot, when he flies his float-equipped Aeronca 200 mi. on an 8-gallon tank of fuel in a flight from North Beach, Long Island, to Whitney's Landing on the Chesapeake Bay. The previous record was 76.155 mi. The Aeronca weighs less than 770 lb, which establishes a new lightweight classification for seaplanes. *Aero Digest*, July 1935, p. 104.

June 17 French aviator Maryse Hilz sets a new women's altitude record as she takes her 600-hp aircraft over Villacoublay to an altitude of 38,704 ft, bettering her record of 32,114 ft. *Aero Digest*, July 1935, p. 104.

June 20 Three days after Maryse Hilz sets a new women's altitude mark, the Marchesa Carina Negrone breaks it with a flight of 39,511 ft over Celio Airport, Rome. *Aero Digest*, July 1935, p. 104.

June 23 French pilots establish a new world's seaplane distance record on a 2,707-mi. nonstop flight of the Southern Cross from Cherbourg, France, to Ziguinchor, Senegal. *Aero Digest*, July 1935, p. 104.

And During June 1935

—The Coupe Feminine Helene Boucher is founded to encourage flying among women. The first race for this cup is scheduled for Aug. 31, 1935. The award, named after the French aviator, is open to women of all nations; contest rules state that all the competing pilots, crews and passengers must be women. The course ranges from Paris to Buc and then to Cannes. The first to reach Cannes will win a cash prize of 40,000 francs, the second 7,500 francs, and the third 3,500 francs. *The Aeroplane*, June 19, 1935, p. 704.

100 Years Ago, June 1910

June 2 Charles Stewart Rolls, piloting his Wright biplane, becomes the first person to fly across the English Channel and back. A. van Hoorebeeck, *La Conquete de L'Air*, p. 83.

June 9 The first French military flight occurs when pilots Albert Fequant and Charles Marconnet fly from Chalons to Vincennes. A. van Hoorebeeck, *La Conquete de L'Air*, p. 83.

June 13 Charles Hamilton flies round trip from New York to Philadelphia, a distance of 299 mi., in 6 hr 57 min, to win the *New York Times* Prize of $10,000. A. van Hoorebeeck, *La Conquete de L'Air*, p. 84.

June 19 Zeppelin Number 7, known as the Deutschland, completes its first flight. Three days later, Count von Zeppelin pilots the dirigible on a 2½ hour flight with 32 people on board. A. van Hoorebeeck, *La Conquete de L'Air*, p. 84.

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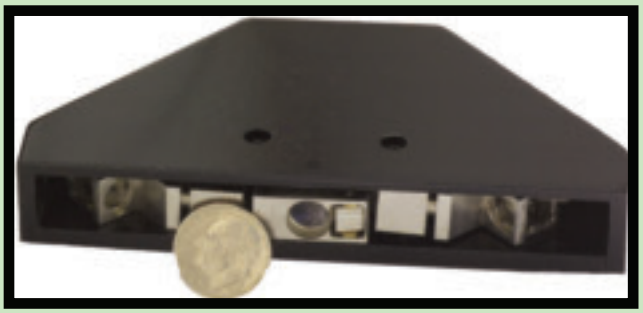

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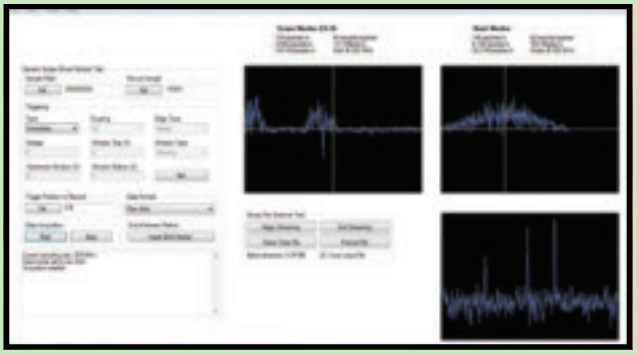

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